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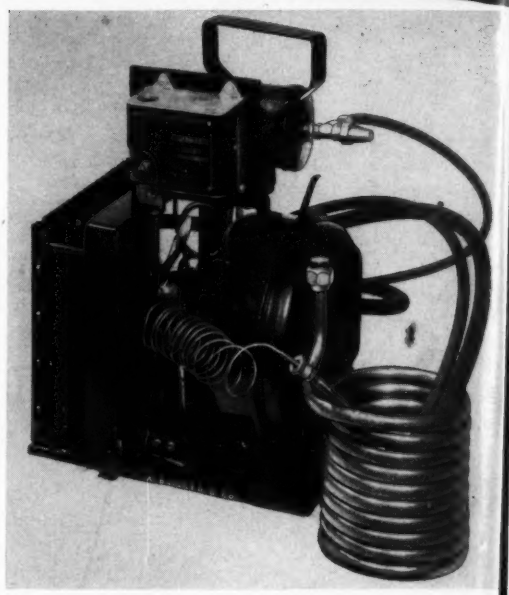

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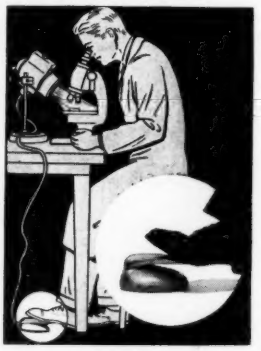

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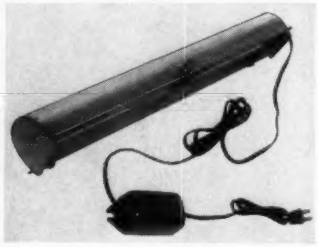

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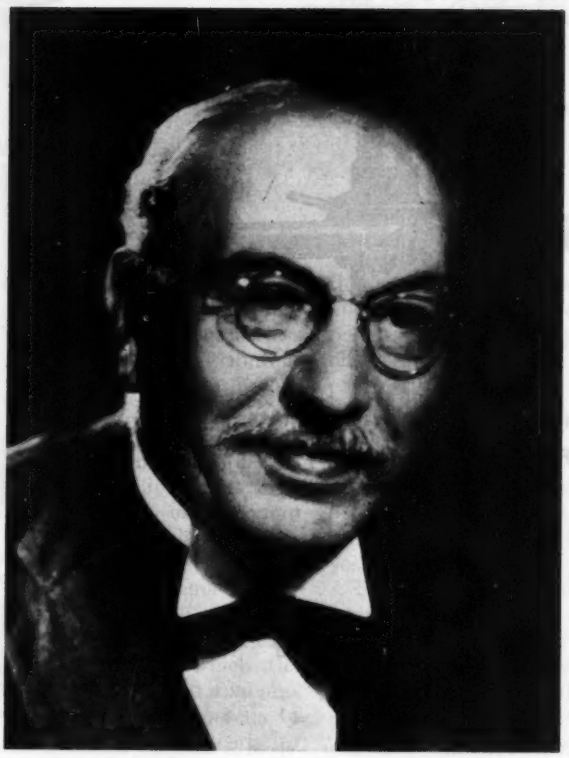

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(See page 13)

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Editor's Outlook

PERHAPS enough has been said about the chemist's need for better habits and better instruction in report writing to make further talk redundant. Nevertheless we have seen fit to publish the excellent contribution to this subject to be found on page 8. It describes an earnest effort to fill this long-felt need at a first-class technical college. The pit in which efforts of this sort have heretofore bogged down is the almost bottomless morass of student indifference and hostility. Anything that smacks of "English Composition" excites more student antagonism than any other curricular or extra-curricular element in the college experience—unless it be compulsory chapel! A little progress seems to have been made in overcoming this.

No one can very successfully defend the old-time method of report writing, according to which the student follows meticulously the directions in a laboratory manual, and then closes it up and proceeds to "write up" his "experiment." Generally he ends up about where he began—often in understanding as well as in written copy. His "write-up" often differs from the laboratory manual in little other than the tense of the verbs. It is altogether unrealistic to believe that this constitutes training in any kind of "scientific method." The result has caused many a good teacher to give up the effort to combine training in the arts of communication with the other objectives of laboratory work and to say resignedly: "What's the use?"

Even under better circumstances, laboratory reports are equally laborious and unrequiting to student and instructor. The student is never quite convinced that the report is a justifiable requirement of him, and feels that it is an element incompatible with the more objective aspects of laboratory work. The instructor soon finds himself in collusion with the student in defeating the latter's best interests, anticipating the meaning of ungrammatical expression and accepting a poorly composed piece of work simply because he has no time to do otherwise. He excuses himself with: "Well, he apparently knows what it is all about, anyway." Consequently, we revert to time-saving devices such as a fill-in manual. If this has "tear-out" pages it has a double advantage: it preserves the "secret" of the experiment from others who might later pick up the book, and it insures that the publisher will be able to sell a new book to the student who takes the course next year.

This is "old stuff" to teachers, most of whom have certainly thought the problem through before—generally to frustration. Perhaps some of those who have long since given it up may get a new burst of enthusiasm from the article by Doody and Gibbens.

In any event, an editor will perhaps be excused for thinking this question especially important. After all, he is one of those who suffer most from its lack of solution. If our students could only be taught to write understandingly, interestingly, and restrainedly—and moreover, be somehow brought to take pleasure in *doing* so—we could eventually offer our readers more articles as readable and interesting as this one is. The vital art of *communication* is one of the necessary accomplishments of a successful scientific worker, and we too often compel our students to learn this the hard way, in the hard-knocking world of industry and competition. The adjustment to the after-college world is hard enough at best; a young man should not be compelled to attempt it without at least some degree of competence in this important art.

And so, any step we can take in this direction is worth taking—even if it be a small one.

ELECTRONEGATIVITIES IN INORGANIC CHEMISTRY. II

R. T. SANDERSON
State University of Iowa, Iowa City, Iowa

In the first paper (*1*) of this series, it was shown that the relative electronegativities of the active elements are indicated by the compactness of their atoms, relative to the compactness of atoms of the inert elements. In other words, if a given atom has a relatively high attraction for outside electrons, this is evidenced by the fact that its own electrons are held close together despite their mutual repulsion. Conversely, if the atom has a low attraction for outside electrons, its own electrons are likewise more loosely held and on the average, farther apart. The quantitative measure of the electronegativities of atoms is the "stability ratio" (*SR*), which is the ratio of the average electronic density of an atom to that of a hypothetical isoelectronic inert atom. The purpose of this paper is to demonstrate the application of these ideas of electronegativity to ions and to the estimation of the partial charge on combined atoms.

THE NATURE OF CHEMICAL COMBINATION

If two atoms, each having an attraction for outside electrons, come together, each atom will exert its attraction for the outermost electrons of the other. Whether an electron bond will form depends on the availability of low-energy orbitals and electrons on each atom. If each atom has one such orbital available to accommodate one electron of the other atom, and also one electron to be shared by the other atom, a stable covalent bond may form. If each atom has available a low energy orbital, and one atom has two electrons in this orbital but the orbital of the other atom is empty, then a coordinate bond may be formed.

It seems entirely reasonable to suppose that the electrons participating in a covalent bond must assume a time-average position in which they are equally attracted to both atoms. If the atoms were initially alike in electronegativity, this means that although at any given instant the valence electrons may be more closely associated with one nucleus than with the other, on the average they are associated equally with both. If, however, the atoms joined by a covalent bond were initially unequal in electronegativity, the valence electrons can have reached a state of equal attraction by both atoms only if the atoms have become adjusted to an equal electronegativity in the process of combination. A simple, visualizable explanation of such an adjustment (*2*, *3*) is the following. In the molecule, the valence electrons spend more than half time more closely associated with the atom which initially attracted them more. A partial negative charge is thus acquired by this atom, which causes expansion of the electronic sphere. The valence electrons become less closely associated with the nucleus as the result of this expansion, so that the attraction diminishes. The other atom acquires a partial positive charge, which causes contraction of its electronic sphere, allowing the valence electrons to become more closely associated with its nucleus and thus increasing the attraction. In this manner, the attractions of the two nuclei for the valence electrons become equalized. The adjustment is crudely illustrated in Figure 1.

It is postulated that atoms which are initially different in electronegativity change in average electronic density in the process of combination until they are of equal electronegativity in the molecule. The question of how to evaluate this particular intermediate electronegativity has as yet been answered only empirically. An answer which has found considerable support in recent comprehensive studies of bond lengths (*2*, *3*, *4*) is that the intermediate electronegativity, or *SR*, of a molecule is the geometric mean of the *SR*'s of all the individual atoms before combination.

These ideas have many useful applications. One is to the interpretation and estimation of bond lengths.

BOND LENGTHS

Polar covalent bonds are characteristically shorter than the sum of the nonpolar covalent radii of the joined atoms (*5*). The stability ratio theory not only provides a qualitative picture explaining this shortening but also enables the quantitative estimation of bond lengths (*2*,*3*). The qualitative picture is that of expansion and contraction of electronic spheres toward an equal intermediate electronegativity. When, as is usual, the linear contraction of the initially less electronegative atom exceeds the linear expansion of the initially more electronegative atom, the resultant bond length is less. Each successive addition of a more electronegative atom results in further contraction of the less electronegative atom, and consequently in successive "shortening" of the bond. The quantitative estimation of bond lengths depends on the relation of the electronegativity to the radius. The single bond length is taken as the sum of the radii of the atoms *as they are in the molecule*. These radii may be estimated by use of the equation:

$$r = \sqrt[3]{Z/4.19\ SR_m\ ED_i}$$

The effective radius of the atom in the molecule is r, SR_m is the geometric mean stability ratio of all the atoms in

the molecule, and ED_i is the "most stable" electronic density corresponding to electronic number Z.

For example, the adjustment of silicon and chlorine atoms to a common electronegativity in silicon tetrachloride requires the silicon atom to contract in radius by 0.17 Å. while each chlorine atom expands only 0.04 Å. Consequently the bond length is observed to be 2.00 Å (*6*) (1.97 by this calculation) whereas the nonpolar covalent radius sum is 2.10 Å.

ELECTRONEGATIVITIES OF IONS

Other applications of these ideas are to the interpretation of the properties of combined atoms and of molecules in terms of their electronegativities. Thus if an atom has increased in electronegativity by combining, it must have acquired a partial positive charge, and if it has decreased in electronegativity by combining, it must have acquired a partial negative charge. This knowledge in itself can be very usefully applied, but a more complete understanding could be approached if the exact charge on each combined atom could be determined. Very interesting progress in this direction has been made by assuming that the change in electronegativity is linear with charge. Thus if the electronegativity change undergone by M in forming the compound MX is one-fourth the change undergone by M in forming the M^+ ion, the partial charge on M in MX is 0.25 (of the electronic charge). For such estimates, it is necessary to know the electronegativities of ions.

Qualitatively, it is easy to see that the removal of electrons from the electronic sphere surrounding an atomic nucleus will increase the electronegativity, and that the addition of electrons will decrease it. Positive ions will therefore always be more electronegative than the corresponding atoms, and more so, the greater the ionic charge. Similarly, negative ions will always be less electronegative than the corresponding atoms. The quantitative evaluation of the electronegativity of ions, however, presents a more difficult problem.

Cations

A correlation between electron affinity of the halogens and their electronegativity has been observed (*1*). In general, such a correlation is to be expected for any atom or ion whose predominant chemical tendency is to attract electrons. This of course applies to positive ions. The total energy necessary to remove electrons to form these ions should therefore, with opposite sign, be an indication of the tendency of these ions to take on electrons, their electronegativity, or their electron affinity. This total energy is known for many ions as the sum of the successive ionization potentials. Any electronegativity values assigned to positive ions, then, should follow the same relative trend as the sum of the ionization potentials.

Electronegativities from Crystal Ionic Radii. As one approach to the problem, use may be made of the crystal

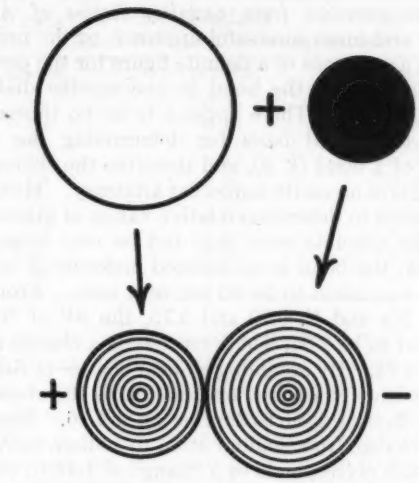

Figure 1. Representation of Combining of Atom of Low Electronegativity with Atom of High Electronegativity

ionic radii given by Pauling (*7*). These values very successfully give internuclear distances observed in many ionic crystals, but whether or not they are applicable to the calculation of suitable electronegativity values is in some doubt. Negative ions, being relatively low in average electronic density, are relatively polarizable, and in a crystal environment where they are surrounded by electronegative cations may reasonably be expected to occupy more space and thus have larger radii than in the absence of such cations. However, cations are much less polarizable. One might expect their crystal radii to be suitable for the calculation of useful stability ratios. Values calculated from these radii are plotted in Figure 2 against the

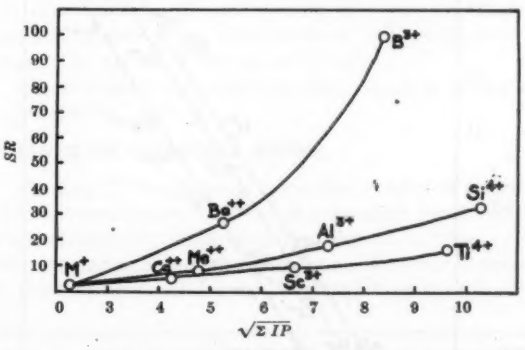

Figure 2. Cation Electronegativities and Ionization Potentials (SR's Calculated from Crystal Ionic Radii)

square root of the sum of the ionization potentials necessary to produce the ions. Here it is shown that although a smooth relationship exists for each isoelectronic series of ions, there is no such relationship for cations in general. If the assumption of such a relationship is valid, then the crystal ionic radii appear from this study to be inappropriate for evaluating the electronegativities of cations.

Electronegativities from Stability Ratios of Atoms. Another and more successful approach to the problem involves acceptance of a definite figure for the per cent ionic character of the bond in one specific diatomic binary molecule. There appears to be no thoroughly reliable theoretical basis for determining the exact polarity of a bond (*8*, *9*), and therefore the choice of a standard is of necessity somewhat arbitrary. However, it is possible to determine relative values of interest, in which the absolute error may not be very large. In this work, the bond in an isolated molecule of sodium fluoride was taken to be 90 per cent ionic. From the *SR*'s of Na and F, 0.70 and 5.75, the *SR* of NaF is calculated to be 2.01, which represents a change in *SR* for F of 3.74. By assuming a linear change of *SR* with per cent ionic character, one calculates the change in *SR* from fluorine atom to fluorine ion as 4.16. Similarly the *SR* change from sodium atom to sodium in NaF is 1.31, which corresponds to a change of 1.46 to sodium ion. The *SR* value for Na^+ is therefore 1.46 + 0.70 or 2.16. That for F^- is 1.59.

The procedure for calculating the *SR*'s for other cations is to determine the molecular *SR* for the appropriate fluoride, and from this, the change in *SR* undergone by fluorine. The ratio of this change to 4.16 indicates the per cent ionic nature of the bond. The ratio of the change undergone by the other element to the per cent ionic nature of the bond gives the change expected for a completely ionic bond. This change, added to the *SR* of the uncombined element, gives the *SR* of the cation. In this manner, *SR* values

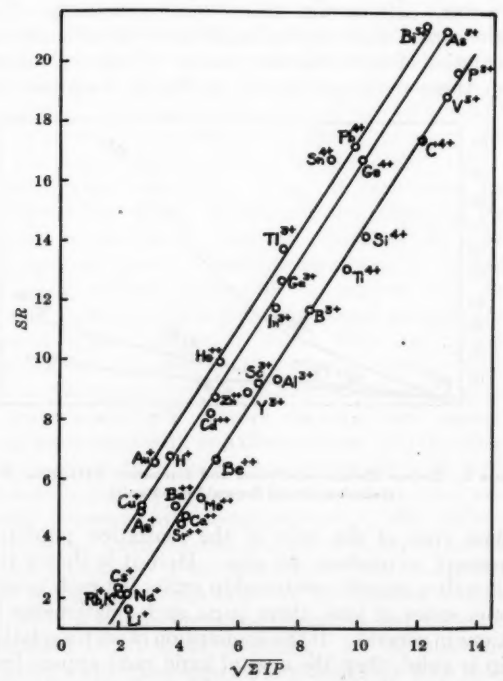

Figure 3. Cation Electronegativities and Ionization Potentials (*SR*'s Calculated from Atomic *SR*'s)

TABLE 1
Electronegativities of Some Cations
(*a*) Calc. from atomic *SR*'s
(*b*) Calc. from ionization potentials

Ion	*Electronegativity* (*a*)	(*b*)	*Ion*	*Electronegativity* (*a*)	(*b*)
Li^+	1.6	2.2	Rb^+	2.2	1.8
Be^{++}	6.7	6.7	Sr^{++}	4.5	4.9
B^{3+}	11.7	11.6	Y^{3+}	8.9	8.4
C^{4+}	17.4	17.4			
			Ag^+	4.9	5.1
Na^+	2.2	2.2	Cd^{++}	8.2	8.7
Mg^{++}	5.4	6.0	In^{3+}	11.8	12.0
Al^{3+}	9.4	9.9	Sn^{4+}	16.7	14.9
Si^{4+}	14.2	14.5	Sb^{5+}	19.4	19.8
P^{5+}	19.6	19.2			
			Cs^+	2.4	1.7
K^+	2.2	1.9	Ba^{++}	5.1	4.7
Ca^{++}	4.8	5.2			
Sc^{3+}	9.2	8.9	Au^+	6.6	6.8
Ti^{4+}	13.1	13.5	Hg^{++}	10.0	10.2
V^{5+}	18.8	18.6	Tl^{3+}	13.8	13.4
			Pb^{4+}	17.2	17.2
Cu^+	5.1	5.1	Bi^{5+}	21.2	20.8
Zn^{++}	8.8	8.9			
Ga^{3+}	12.7	12.3	H^+	6.8	6.5
Ge^{4+}	16.7	16.5	NH_4^+	4.4	
As^{5+}	21.0	20.9	H_3O^+	4.8	
			NO^+	6.8	
Cu^{++}	7.9		SO^{++}	8.4	

for many common simple cations have been calculated. They represent not the electronegativities of the isolated gaseous ions but the electronegativities in the gaseous compounds if the bonds were completely polar. The condensation of gaseous molecules to form ionic crystals is believed to be accompanied by significant readjustment of the electronic spheres. The effect of this readjustment on electronegativity is not yet known.

It must be emphasized that at best this method gives only a rough approximation. However, the resulting values are of considerable interest. These values are plotted in Figure 3 against the square root of the sum of the ionization potentials. It will be observed that although the relationship is not perfect, all cations which are isoelectronic with atoms of the inert elements fall roughly on the same straight line. Cations of the 18-shell type fall on another straight line, parallel to the first, except for the 18-shell cations of the 6th period, which form a third parallel line. These lines may be represented by the equation:

$$SR = 1.54a - b$$

where a is the square root of the sum of the ionization potentials required to produce the ion from the atom, and b is -1.33, 0.85, or 1.90. Cation electronegativity values determined as described earlier are compared with values calculated from ionization potentials by use of the above equation in Table 1. Unfortunately, just as in the case of the atomic stability ratios (*1*), the least certain cationic stability ratios are those of the transition elements. Complete ionization potential data are not available for these elements, either. However, the correct order of magnitude is probably indicated by the described method of calculation.

It is very interesting to observe that the electronegativities of some cations may be considerably higher than those of the most electronegative elements, oxygen and fluorine. This is of course in harmony with the fact that such cations have ordinarily no separate existence. Either they do not exist at all, or they are solvated or otherwise complexed, by which process their electronegativity is much reduced. For example, the stable barium ion has an electronegativity of about 5, but the hydration energy of approximately 300 kg.-cal./mol certainly must indicate a substantial effective reduction of this value. This subject will be discussed further presently.

Revised Electronegativities of Alkali and Alkaline Earth Metals. The electronegativities of the alkali and alkaline earth metals, as calculated from average electronic densities (*1*), are not quite in the order expected from the chemical properties. In the plot of Figure 3, these metals are likewise not well aligned. However, the linear relationship suggests that the *SR* values may be corrected on the basis of the ionization potentials. Ionic electronegativities so obtained may be used to calculate corrected atomic electronegativities. Values thus calculated are listed in Table 2. These revised values appear to agree better with chemical properties than the values determined from average electronic densities, although they are inferior in bond-length calculations. Substitution of the revised values for those reported previously (*1*) is suggested, until a more absolute method of evaluating electronegativities of these elements becomes available.

TABLE 2
Some Revised Electronegativities

Element	*Old SR*	*Revised SR*
Li	0.46	0.74
Na	0.70	0.70
K	0.71	0.56
Rb	0.73	0.53
Cs	0.81	0.49
Be	1.87	1.91
Mg	1.30	1.56
Ca	1.05	1.22
Sr	0.96	1.10
Ba	1.20	1.02

Anions

Electronegativity values for simple anions may be estimated as described earlier for the fluoride ion. The procedure is similar for complex anions, and can perhaps best be described by an example. To determine the electronegativity of the sulfate ion, the *SR* of SO_4 is calculated, just as if it were a molecule. This is 4.97. The *SR* of Ag_2SO_4 is then calculated to be 3.99. In the process of forming silver sulfate, silver atom has increased in *SR* from 2.30 to 3.99, or by 1.69. As determined from AgF, the increase in *SR* from silver atom to silver ion, Ag^+, is 2.64. Hence the ionic character of the bond in silver sulfate is 1.69/2.64 or 64.0 per cent. If the decrease in *SR* of the sulfate group in forming silver sulfate is 4.97 − 3.99, or 0.98, for 64 per cent ionic character, then for 100 per cent the decrease would be 0.98/0.64 or 1.53. The *SR* or electronegativity of the SO_4^{--} ion is then 4.97 − 1.53, or 3.44. The average of several determinations, using different metals, is 3.45.

The reason for using a more electronegative metal than sodium in this calculation becomes apparent by comparing the electronegativity of sulfate ion with the value of 2.16 for sodium ion. Evidently there is a limit to the applicability of the postulate that atoms come to the same intermediate electronegativity in the process of combining to form a molecule. When a group of atoms, especially if relatively high in electronegativity, combines with atoms of very low electronegativity, it frequently happens that even when the atoms of low electronegativity, the metal atoms, have given up their valence electrons completely to the nonmetal group, these electrons are insufficient to reduce the electronegativity of the nonmetal group to the value of the positive ions. The sulfate, nitrate, or perchlorate groups, for example, are so highly electronegative to begin with that they are still fairly high in electronegativity even after taking over completely the electrons furnished by the available metal atoms. Consequently the alkali metal salts containing these anions are considered to be completely ionic but the anions are more electronegative than the cations. The relation of this fact to coordination chemistry will be discussed in the following paper.

Another interesting result of these calculations is that negative values of electronegativity are obtained for oxide, O^{--}, and sulfide, S^{--} ions. The significance of negative values of electronegativity is that they are consistent with the estimation of electron affinities of these elements, which show that although energy is released when an oxygen or sulfur atom takes on one electron, the acquisition of a second electron actually requires the absorption of a large amount of energy, in excess of 100 kg.-cal./mol.

Electronegativity values for some common anions are tabulated in Table 3.

CHARGE ON COMBINED ATOMS

Pauling (*7*) has devised a familiar empirical relationship between ionic character of a covalent bond and the electronegativity difference between the atoms. The relationship is based numerically on the ionic character of the hydrogen halides, as calculated from the observed

TABLE 3
Electronegativities of Some Anions

Ion	*EN*	*Ion*	*EN*	*Ion*	*EN*	*Ion*	*EN*
O^{--}	Neg.	F^-	1.59	SO_3^{--}	3.01	$H_2PO_4^-$	3.87
S^{--}	Neg.	SH^-	2.20	HPO_4^{--}	3.32	*H_2O*	*4.04*
H^-	0.29	CN^-	2.37	SO_4^{--}	3.45	NO_3^-	4.06
I^-	0.42	OH^-	2.50	$C_2O_4^{--}$	3.45	HSO_4^-	4.09
(S^-)	0.58	PO_4^{3-}	2.50	$HCOO^-$	3.48	ClO_3^-	4.17
Br^-	0.84	BH_4^-	2.76	NO_2^-	3.70	BF_4^-	4.23
Cl^-	1.08	CO_3^{--}	2.92	HCO_3^-	3.81	ClO_4^-	4.39
(O^-)	1.23	SCN^-	2.95	HSO_3^-	3.87		

bond lengths and dipole moments. The original relationship was based on an assumed value for the dipole moment of HF, and was revised after the actual value for HF was determined experimentally and found to be lower than originally assumed (*10*). The possible inaccuracy of calculating the ionic character from the dipole moment, referred to earlier, has been stated by Coulson (*9*) as follows: "Indeed, once it is recognized that a hybrid atomic orbital does not possess a center of symmetry, as the pure *s*, *p* orbitals do, then it follows that the center of position of the electron cloud of the orbital is separated from the corresponding positive charge on the nucleus. Thus it is clear that whenever there is hybridization, there will be an atomic-dipole and we can no longer use the total dipole moment for a bond to infer the relative weights of covalent and ionic parts." Aside from this objection, the stability ratio theory implies that Pauling's relationship can only apply strictly to diatomic molecules, because this relationship does not take into account the effect which each bond in a more complex molecule is considered to have on all the other bonds (*11*, *12*).

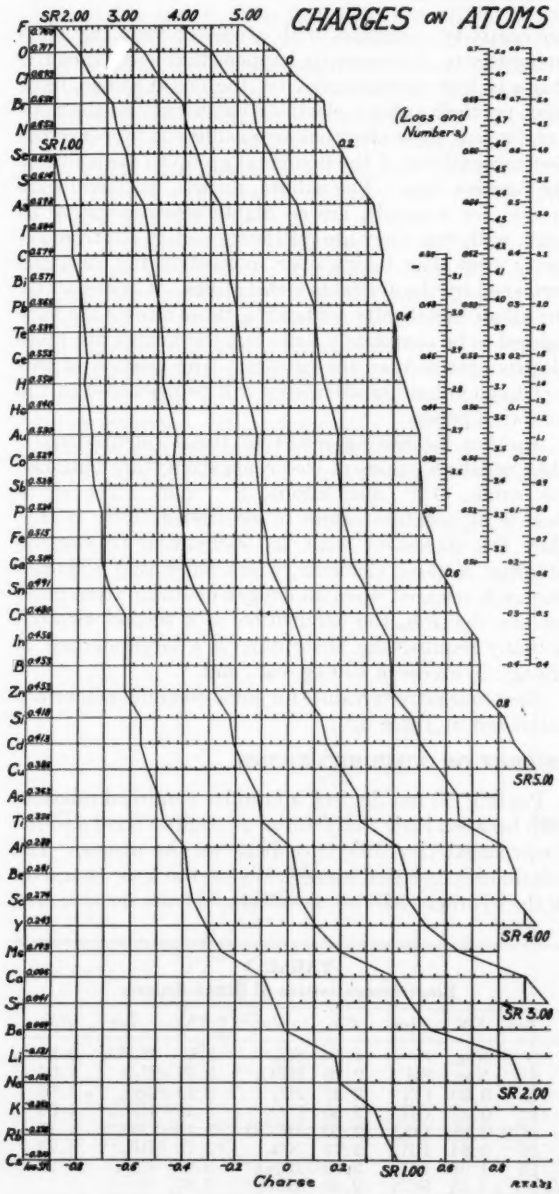

Figure 4

The use of *SR* values in recognizing the existence and type of charge on a combined atom has previously been described. It can now be pointed out that the assumptions which were the basis for the calculation of electronegativity values for cations and anions may be used for determining actual values of the partial charges on combined atoms. If the change in *SR* is linear with the per cent ionic character of an atom, then the partial charge on an atom in combination is simply the ratio of the change in *SR* undergone by the atom in the process of combining to the change that it would undergo in acquiring unit charge. The latter change for a polyvalent atom is simply the total change accompanying ionization divided by the valence, or $\Delta SR_{izn}/n$. The change undergone in the process of combining is equal to the difference between the SR_m of the molecule and the SR_e of the free element. The charge, δ_e, on an atom is thus:

$$\delta_e = nSR_m/\Delta SR_{izn} - nSR_e/\Delta SR_{izn}$$

For a given element, only SR_m is variable. The sign of the charge is of course negative if $SR_e > SR_m$ and positive if $SR_m > SR_e$. Values for $nSR_e/\Delta SR_{izn}$ and for $\Delta SR_{izn}/n$ for a number of elements are given in Table 4. Alternatively, the partial charges on combined atoms may be estimated from the stability ratios of the molecules or complex ions by use of the chart, Figure 4. This chart includes, for convenience, data for determining the *SR* values of molecules.

To illustrate the use of these methods, the charges on the atoms of perchloric acid (*SR* 4.84) and perchlorate ion (*SR* 4.39) may be estimated. For chlorine, in $HClO_4$, divide 4.84 by 3.85 from Table 4, which gives 1.29, and subtract 1.28, which gives −0.01 for the charge on chlorine. Alternatively, interpolate on the horizontal line opposite chlorine in the chart, Figure 4, to *SR* 4.84, and read off the corresponding charge on the horizontal scale. For hydrogen, divide 4.84 by 3.26 from the table, which gives 1.48, and subtract 1.09 from the table, leaving 0.39 for the charge on hydrogen. For oxygen, divide 4.84 by 3.98, which gives 1.22, and subtract 1.31, which gives −0.09 for the charge on each oxygen atom. The total negative charge, on four oxygen atoms plus one chlorine atom, is −0.37, which is as close to the positive charge of 0.39 on hydrogen as can be expected when the charge is only calculated to the nearest hundredth of an electron. Similarly, for perchlorate ion, the charge on chlorine is found by dividing 4.39 by 3.85 and subtracting 1.28 to give

−0.14. The charge on each oxygen atom is found by dividing 4.39 by 3.98, and subtracting 1.31 to give −0.21. The total charge on the perchlorate ion is then −0.84 plus −0.14, giving −0.98, which checks satisfactorily with the unit negative charge actually on the ion.

TABLE 4
Values for Calculating Charge on Combined Atoms

	$\Delta SR_{ion}/n$	$nSR_e/\Delta SR_{ion}$		$\Delta SR_{ion}/n$	$nSR_e/\Delta SR_{ion}$
H	3.26	1.09	Zn	2.97	0.96
Li	1.50	0.49	Ga	3.15	0.99
Be	2.41	0.79	Ge	3.37	1.07
B	2.95	0.96	As	3.42	1.14
C	3.39	1.12	Se	3.64	1.17
N	3.77	1.19	Br	3.74	1.21
O	3.98	1.31	Rb	1.28	0.41
F	4.16	1.38	Sr	1.93	0.57
Na	1.46	0.48	Y	2.39	0.73
Mg	2.22	0.70	Ag	2.64	0.87
Al	2.47	0.79	Cd	2.83	0.91
Si	2.89	0.91	In	2.97	0.96
P	3.26	1.02	Sn	3.07	1.01
S	3.54	1.16	Sb	3.21	1.05
Cl	3.85	1.28	Te	3.39	1.07
K	1.31	0.43	I	3.42	1.12
Ca	1.98	0.62	Cs	1.21	0.41
Sc	2.45	0.77	Ba	1.82	0.56
Ti	2.69	0.84	Au	3.22	1.05
V	3.15	0.99	Hg	3.25	1.07
Cr	3.07	0.98	Tl	3.39	1.06
Fe	3.16	1.03	Pb	3.35	1.10
Co	3.20	1.06	Bi	3.48	1.09
Cu	2.71	0.90			

It is interesting that the ionicity of the hydrogen halides as calculated from dipole moments and bond lengths agrees fairly well, despite objections previously mentioned, with atomic charges calculated as described above, except for hydrogen fluoride: HI 5, 4; HBr 13, 14; HCl 17, 19; but HF 43, 30.

In conclusion, two limitations to the described method of estimating the charges on combined atoms should be clearly understood. The first is that the very assignment of a specific charge, to an individual atom of so complex an electrical system as a molecule, implies a molecular model which is oversimplified and therefore only a crude approximation of the actual molecule. The second is that the net charge distribution represented by the experimentally determined electric dipole moment may be the resultant, especially in relatively complicated molecules, of several factors, of which the bond polarity resulting from initial electronegativity differences is only one. Consequently the partial charges estimated as described are to be regarded as representing only that component of the over-all charge distribution which would be expected from electronegativity differences. One further point which should be kept in mind is the arbitrariness of assigning 90 per cent ionic nature to NaF. The relation among charges is of course independent of this choice, but the absolute values given in this and the following paper would be altered, for example, by a factor of 0.855 if NaF were only 77 per cent ionic. Notwithstanding these limitations, the information available from this method can be very useful in interpreting the facts of chemistry. The following paper of this series will be devoted to specific applications of such information.

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MERCK GRADUATE FELLOWSHIP IN ANALYTICAL CHEMISTRY

Applications are again being received for the Merck Graduate Fellowship in Analytical Chemistry, financed by Merck & Co., Inc. and administered by the A. C. S. The annual stipend is $2500. The place of study must be an institution whose undergraduate course of instruction in chemistry is approved by the Society. In Canada, the institution selected must be approved by the Chemical Institute of Canada and the American Chemical Society.

A fellowship will be awarded to the applicant believed capable of contributing most to the advancement of the theory and practice of analytical chemistry during the fellowship and in the future. It will be voted contingent upon the successful candidate's obtaining acceptance from the institution and professor selected for the study program sponsored.

Application blanks may be obtained from the American Chemical Society, 1155 Sixteenth Street, N. W., Washington 6, D. C. They should be completed and returned to the Merck Fellowship Committee, at the same address, along with letters of recommendation and transcripts of credits. Deadline date for receipt of all material is February 1, 1954.

A REPORT WRITING PROGRAM AT PURDUE

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For the past four summers the juniors in chemical engineering at Purdue University have found instruction in report writing superposed upon, and included as a part of, their unit operations laboratory course. This program of instruction in report writing goes back to the early 1940's, when it also ran for a period of four summers and then, because of the exigencies of war, was discontinued. In the summer of 1950 it was reinstituted by Professor R. Norris Shreve, then head of the School of Chemical and Metallurgical Engineering.[1]

Aware of the general complaints from industry about the writing ability of engineers, the School of Chemical and Metallurgical Engineering saw an opportunity to provide teaching in report writing at a time and in a course where every future graduate of the School would make practical application of his instruction. The unit operations laboratory, regularly scheduled in the summer between the junior and senior years, is required for graduation and thus no student would "escape"—or be denied the privilege of (according to the point of view)—instruction which he would put to valuable use in his course and, soon after, presumably, in his industrial career.

HISTORY OF THE PROGRAM

The unit operations laboratory course has had the same time schedule for the past four summers. It has run throughout the day from 7:30 A.M. to 12 noon and from 1:00 P.M. to 5:30 P.M. for the full eight weeks of the summer session. Students have been divided into two approximately equal groups, one group attending in the morning, the other in the afternoon. The course has been under the general supervision of a full-time staff member, and he has been aided by graduate assistants.

During the first summer the scheduled class activities of the students included doing the experiment, making the required calculations, and writing the reports (which included drawing sketches of apparatus and making graphs). Though the course was theoretically self-contained, actually much of the graph-making and the writing was done on outside time. When it is considered that the students had twelve reports to do, including three formal reports, and that many of them, perhaps most, were carrying two three-hour courses besides the laboratory course, there can be no doubt that they were heavily loaded with work. This load is mentioned because of its effect upon the students' attitude toward the lessons in report writing and toward the supervision and evaluation of their writing.

Many of the students were veterans of World War II and older than college students now or those of the 1930's and early 1940's and they were not as submissive as younger students are. Thus, when they learned that an English teacher had been engaged to give them lessons in report writing and to read some of their reports, thus adding to their burden, they either raised an outcry or at best became passively sullen. At any rate, the English program was not away to a favorable start.

The program which was set up called for eight hours of class instruction per student, plus individual conferences as they might be needed. The English instructor was to read the three formal reports which each student wrote and to give them a report writing grade or, as the students came to call it, an "English" grade. This grade was to count as 25 per cent of the total grade for the combined experimentation and report. Even the informal reports were to be given an "English" grade by the laboratory instructors.

It had been planned to include instruction in report writing in general as part of the eight hours allotted to instruction in reports. About the second week, however, the discovery was made that, though talk about their own unit operations laboratory reports would evoke some interest and attention, the students had already grown so weary and sleepy from their heavy schedule that they hardly stirred from their lethargy at mention of report writing problems which did not bear a direct relationship to their own immediate work.

The attempt was not dropped to teach them about other types of reports, but it did go "underground." Comments were slipped into the lectures and discussions here and there, but the subject was never dwelled upon. As the summer progressed, waning interest was revived by drawing on their own reports for material to be used in the lectures. Examples of good and bad summaries, descriptions of apparatus, accounts of procedure, discussions of results, etc., were mimeographed and distributed for class comment.

The lessons ended with the fifth week of summer school, and private conferences and consultations supplanted them. The bulk of the reading was done in weeks 5–8. The students showed a marked interest in their "English" grades and a genuine curiosity to see how they were doing, what errors they had made, and what praise their papers had received.

[1] When Professor Shreve retired from the headship in the fall of 1951, the program was continued under his successor, Dr. E. W. Comings.

By the end of the summer a notable softening of attitude toward the English teacher and the work he was doing had appeared, though a good many "unreconstructed, unconverted" students looked with disapproval, if not with dislike, upon the "whole business." The chemical engineering professor directing the unit operations laboratory course was not excluded from the disapproval. In view of this hostile attitude, it was particularly gratifying when one of the disapproving students, on returning to the campus in the summer of 1952, made special calls on the English teacher and the chemical engineering professor to express appreciation for the training and practice in report writing which he had received.

In the second summer, 1951, the course followed the setup of the previous summer except for minor changes. The number of lessons in report writing was reduced from eight to six, partly to lighten the student's load and partly because it had become evident during the previous summer that little could be done directly about report writing in general or about English composition in general. The lessons had to concern reports for unit operations or student interest dropped off to near zero.

Student attitude was much better during the second summer. Though many students looked on the report writing lessons and the grading of their writing as necessary evils, there was little or none of the smoldering resentment of the preceding summer. Their acceptance was no doubt influenced by the fact that the report writing program seemed to them to have become an integral part of the course and not the imposition of extra work, as it had seemed a year earlier.

This acceptance contrasted with the attitude of about 30 metallurgical engineering students who in this second summer were included in the report writing program. They were the first to "suffer" this addition to the course, and their feelings almost duplicated those of the chemical engineering students of the summer before and they remained rebellious throughout the eight-week summer term. The setup in metallurgical engineering was different from that in the unit operations course. A group of experiments covered some phase of metallurgy such as igneous chemistry, electroplating, electrorefining, and steel making, and each student was required to write a long formal report on each of three of the phases. These reports were read for "English" too, and six lessons on report writing also became a part of this program.

The summer of 1952 brought a drastic change in the unit operations laboratory course. Formal reports were eliminated and informal reports were substituted for them. The number of reports was reduced from 12 to 8. Two new assignments were added—a 1000-word research paper dealing with the latest developments of a unit operation or a phase of a unit operation and a one-and-a-half hour examination on Saturday morning which covered the week's work.

So that the course would be made self-contained, the reports were written in a definitely allotted class time and under the supervision of an instructor. The theory section, which had run to many pages in former summers, had to be cut to a few paragraphs because of the time restriction. In other sections, such as procedure and discussion of results, the student felt a pressure to make every word count. The results of the new plan proved satisfactory beyond expectations. Students, having heard stories of the long hours spent outside class time on reports, were gratified at getting their work done in class, and the instructors were pleased at having much less reading to do per report and at finding students expressing themselves with greater conciseness, accuracy, and force.

The research paper also proved successful, from the point of view of both the students and the instructors. For the selection and later limiting of the subject, its manner of treatment, and the organization of the paper, the student consulted the engineering professor on technical matters, the English professor on nontechnical matters. A schedule was established to check, and thereby stimulate, the progress of the student's research. By given dates he had to submit his bibliography and his note cards to the English instructor for approval. When anything appeared out of line with subject, bibliography, or notes, the student was sent to the engineering professor for a further check.

The completed papers were given two grades, each counting 50 per cent of the final grade, which itself counted the equivalent of a grade on a report. The chemical engineering professor in charge of the unit operations course read all the research papers, not turning them over to his assistants for grading, and evaluated them for technical treatment and content, and the English professor evaluated them for general treatment and organization, handling of source material, and documentation.

The same plan was followed as before with the metallurgical engineering students. Added stress was placed upon conciseness and readability, and the reports were *shorter* and better than those of the preceding summer. Some of this improvement—perhaps much of it—was due to the instructor's having profited from his teaching and *learning* experience of the year before. He had formulated more definitely in his own mind ideas and opinions on how the reports could be best organized and presented, and his added assurance in teaching the lessons and supervising the writing of reports had a marked result upon the quality of the report writing produced. Of course, what is said here applies equally well to the instructor's experience in the unit operations course. In fact, every summer's experience taught valuable lessons, including knowledge of the chemical and metallurgical engineering involved.

PRESENT SETUP

The development of the report writing program has been traced in considerable detail from its reinception in the summer of 1950. The setup in the summer of 1953 was the same as in the preceding summer, the lack

of change testifying to the satisfaction of everyone—students, as well as instructors—with the laboratory course as now constituted. As for the report writing program, it has come to be regarded as a routine part of the course and is accepted matter-of-factly.

Only minor changes were made in 1953 in the report form adopted when the unit operations course was revised for the summer of 1952. At that time some of the parts of a formal report were eliminated from the guide form, namely, letter of transmittal, title page, table of contents, bibliography, and nomenclature; and the requirements for the section on theory were greatly reduced. This past summer, as the summer before, the following guide outline was mimeographed and given to the students on the first day of the course.

Unit Operations Reports

Outline

Cover
Summary (100–200 words)
Statement of the problem
Theory (general principles; no equations)
Apparatus and procedure
Log sheet
Sample calculations
Tabulated results
Correlation and discussion of results
Appendix
Graphs, diagrams, blueprints, laboratory instructions, etc.

Discussion

Cover. Since a title page is omitted, the information on the cover will substitute for it. The cover should thus contain the title of the experiment, the name of the person submitting the report, names of the group or co-workers, the place, the date, the number of the course, the name of the department or school in which the report is submitted, and the name of the instructor to whom the report is submitted. After the heading *File No.* identify yourself by squad and division, as Squad 3A, Squad 2B.

Summary. The summary of any report should permit the reader to find out directly what was done, what results were obtained, and what conclusions were reached without having to read any of the rest of the report. In your reports this summer, the summary should condense the statement of the problem, the description of apparatus, and the account of procedure into no more than two or three sentences and should be concerned mainly with the significant results and conclusions. Results should be given statistically, preferably in tabular form. The summary should be written *after, not before,* the body of the report.

Statement of the Problem. In writing the statement of the problem, avoid assuming a student-teacher (pedagogical) relationship. Do not write: "The object of the experiment was *to study* the principles of vacuum evaporation." Avoid "*to familiarize* the student with. . . ." Forget, for the purposes of the write-up, that you are a *student.*

Theory. The theory will include the general fundamental principles. State them in no more than a page and a half, preferably in only a few short paragraphs.

Apparatus. This is a difficult section to write. It should be more than a listing. Its main purpose, where supplementary illustration is used, is to present a general unified view of the whole and to show the interrelationships of parts. This section should start with a major piece of information, not with a minor detail. Your illustration of the apparatus should be referred to in this section and should be placed immediately after it.

Procedure. Procedure is generally written in chronological order. The extent of the detail included will depend on the needs in a given report-writing situation. The demand may be for this section to be so carefully written that at some future time another investigator could duplicate your experiment by following your account. This summer you will not be expected to go into great detail. You will be expected to tell accurately what you *did,* not what *might have been, could have been,* or *should have been* done.

Correlation and Discussion of Results. In correlating and discussing results, consider their meaning, significance, and validity. Mention influences affecting results both favorably and unfavorably. Be sure to note and, if possible, explain marked discrepancies.

Calculations. Calculations should be in ink and labeled clearly. Equations should be numbered. Symbols should be identified the first time they are used. It is the writer's responsibility to see that the reader understands all symbols and their meaning. Sources for equations should be cited, as Brown, "Chemical Engineering," p. 32, for a first reference to a book and Brown, p. 40, for succeeding references to the same book. If there are more than one edition of a source, the edition should be indicated, as Perry, "Handbook," 2nd ed., p. 216. The important qualification for a reference is that sufficient information be given for the reader to find the source as effortlessly as possible.

Appendix. The appendix is something of a "catch-all." It may contain all the photographs, drawings, tables, and graphs or merely those of lesser importance. It may include, as a permanent part of the record, information not a direct part of the report, as calibration curves for instruments used in the work reported, graphs drawn as intermediate steps in a calculation, details of elaborate calculations, derivations of equations used in the report, etc. It is suggested that your most important graphs and tables be dispersed at appropriate places throughout the report.

Graphs. Graphs should be in ink. They should be self-explanatory without reference to the text. They should be given a full title indicative of the content; it is not enough to head a graph "Thermal Efficiency versus Time." This is merely telling what the coordinates are. Points should be clearly marked. Graphs should carry the date and the draftsman's signature.

Verb Tense. Use past tense for the statement of the problem and especially for the account of procedure. Present tense may be used in the description of apparatus. Mixed present and past may be used in the discussion and correlation of results, past for reference to the results of the experiment, and present for reference to general truths.

Numbering Pages. The report should be bound, and the pages should be numbered.

It is early made clear to students that other forms might work as well as the one recommended for their use and also that any report form must take into consideration the characteristics and peculiarities of the particular situation which it is designed to meet. In the unit operations and the metallurgy courses an academic or a pedagogical situation exists. This admission is made at the outset, but students are advised to minimize this aspect as much as they can in order to make their report writing as specific and practical as possible. Thus they are asked to write that they are trying to determine a certain coefficient or to test the validity of a certain equation and the like and not that they are trying to learn about chemical or metallurgical engineering by familiarizing themselves with certain equipment and certain operations. They are also asked to overlook the fact that the instructor-reader knows more about the subject than they do; to imagine that the reader of the summary has only a general knowledge of the subject; and to write some description of apparatus even though the instructor knows better than they do what the equipment looks like. They are not asked to aim their writing at the English instructor.

It must be admitted that, despite all pretense, the

fact that much of the report has an academic purpose cannot be ignored. The theory section, the sample calculations, the discussion of results and conclusions—all these parts are designed to indicate to the teacher whether the student understands the basic principles of the problem.

The student laboratory report is thus seen to be a sort of "two-headed" composition, part of it being written for one type of reader, part for another. Its preparation, nonetheless, provides the student valuable practice in the organization and presentation of facts in a logical, straightforward, and clear manner. Certainly a student who can write a good laboratory report should have no trouble with an actual industrial report written for a known reader or readers.

The first report or two are liable to be awkward and stilted. Because of the student's preoccupation with form, he tends to neglect sentence structure, grammar, and punctuation. He inadequately distinguishes between results and conclusions, and his discussion of results more often than not is merely a putting into words of his tabulated results and no more. His avoidance of the first person leads him into awkward uses of the passive voice and into a prose full of dangling modifiers. He uses pronouns with the vaguest of antecedents. In short, his writing is liable to be strained, tortured, inexact, and confused.

After he has received the laboratory instructor's criticisms on his first report and the English instructor's criticism on his second and has gained some practice in writing reports, he begins to show improvement. He gains confidence in himself, he starts to "clean up" his writing, he becomes more fluent, and he begins to learn to condense his writing. He still has trouble with dangling modifiers, though he reduces their number. He does not easily correct his faulty use of pronouns, but he makes some progress.

All this time in the report writing sessions the faults of his early reports are being pointed out to him, specific corrections are being made, and examples of good work are mimeographed and passed out, accompanied by the instructor's comment. As previously pointed out, the laboratory instructors give the report writing grade to the reports not read by the English instructor (five out of the eight, since he reads only three), and so the student is never permitted to forget that his writing will constitute an important element in his total course grade at the end of the summer. Furthermore, one of his reports is sent to the Committee on Standards in English, where it is read by one of the Committee readers and marked "Satisfactory," "Unsatisfactory," or "Doubtful." If the paper is unsatisfactory, the writer is asked to appear at the offices of the Committee and to write a test theme. The student is told at the start of the unit operations course that one of his papers (but not which one) will be sent during the summer to the Committee. "Fear" of the results of a bad paper is, thus, still another motivation to the unit operations student to do his best in writing reports.

AN EVALUATION

Four years of trying to teach something about report writing to the students who went through the laboratory courses in that time are enough, we believe, on which to base an evaluation. Frankly and unabashedly, we think that the program has worked. We believe it is good to provide the lessons at the exact time when the information can be put to direct use in the report writing. This is better, in our opinion, than to teach the student in an isolated course and merely hope that what he learns—or is exposed to—carries over at some later time in his laboratory course.

Six lessons are not many, but in this situation seem to be the optimum number. Of course, there is a follow-up to the lessons. Many students come voluntarily to the instructor with their problems of composition, and students whose writing shows up weak on early reports are called in for individual help.

If success has been achieved, it must be attributed in part to the cooperation between the technical instructors and the English instructor. A common complaint of an English instructor teaching engineering and science students is that he cannot understand technical subject matter and is not capable of evaluating it. In the unit operations course the English instructor does not have this worry, for the technical material is evaluated by experts. If a question of English hinges on a technical meaning or interpretation, all he has to do is step to the adjoining office and get the needed help. If he reads about a piece of apparatus used in an experiment and he does not have the slightest notion of what it looks like, he can go into the laboratory and look at it.

Furthermore, the technical reader aids the cause by asking for good English, and the English instructor does his part by insisting on clarity and technical accuracy. To have one buttressing the other and both working toward the same objective impresses the student deeply and stimulates him to do better work than he otherwise might do.

Instructors in the regular school year who have senior chemical and metallurgical engineering students in courses where reports are required are pleased that the students know something about organizing and presenting the results of laboratory investigation. They believe that the program of instruction in report writing is worth following.

Some respects in which the program is not successful have already been indicated. The student is heavily loaded and the imposition of an added load does not produce the best attitude toward the new burden. He is not in a mood to look very far ahead of his present problems and does not take to general instruction about report writing. Even at best, he is likely to think that an English teacher has no business trying to read and in any way evaluate technical material. Incidentally, the more technical knowledge the English teacher has and can accumulate, the more he can break down the barrier between him and the students.

We think, looking back on the first summer from our

four-summer vantage point, that the course administrator who superposes a report writing program on a laboratory course already pretty "tight" and the English teacher who agrees to handle the program are stepping into a situation which in many respects is unenviable. They must be prepared to cope with disapproval, if not with active hostility. They must not be afraid of being unpopular. Even if the work has the value they think it has, they must not expect it to be appreciated at once, or perhaps even for years. But we would say to them that instituting and conducting such a program would constitute a valuable contribution to the training of the science or engineering students under their charge.

PREPARATION OF 2-NAPHTHALDEHYDE

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IN THE course of the preparation of 2-substituted naphthalene compounds for use as plant regulators, an improved method for the synthesis of 2-naphthaldehyde was developed. It was found that N-bromosuccinimide bromination of the relatively inexpensive 2-methylnaphthalene (*1*), by a procedure analogous to that described for 1-methylnaphthalene (*2*), followed by condensation of the crude bromide with hexamethylenetetramine, according to a modified Sommlet procedure (*3*, *4*) afforded the desired product in a 64 per cent over-all yield. This method offers a number of advantages over those previously described (*4–8*).

The procedure follows.

To a solution of 71.0 g. (0.5 mol) of 2-methylnaphthalene (technical grade) in 450 g. of carbon tetrachloride (analytical grade), in a one-liter two-neck round-bottomed flask fitted with a mechanical stirrer and reflux condenser, was added 89.0 g. (0.5 mol) N-bromosuccinimide, and the reaction mixture was stirred and refluxed for 16 hours. The succinimide was filtered off, and the solvent removed under reduced pressure. The resulting brown oil was dissolved in 300 ml. of purified chloroform and added to a rapidly stirred solution of 84.0 g. (0.5 mol) hexamethylenetetramine in 150 ml. of purified chloroform in a two-liter three-neck round-bottomed flask fitted with a dropping funnel, reflux condenser, and glass paddle stirrer, at such a rate as to maintain vigorous refluxing. A white salt-like material settled out almost immediately. The mixture was heated to reflux for 30 minutes, cooled, and filtered. The crystalline hexammonium bromide product was washed with two 100-ml. portions of cold petroleum ether and then dried. Yield, 146.5 g. (79 per cent); m. p., 174–6°C.; calculated Br, 22.12; found, 22.30.

The hexammonium bromide product was refluxed for two hours in 750 ml. of 50 per cent acetic acid solution; then 150 ml. of concentrated hydrochloric acid was added, and the solution was refluxed for five minutes more, then cooled. The aldehyde was extracted from the solution with ether, and recrystallized from a minimum volume of hot *n*-hexane. White crystalline 2-naphthaldehyde, m. p. 58.5-59.5°C (hot stage) was obtained in a 77–80 per cent yield from the hexammonium bromide product, or a 64 per cent over-all yield from 2-methylnaphthalene. Analysis calculated for $C_{11}H_8O$: C, 84.6 per cent; H, 5.16 per cent; found: C, 84.56 per cent; H, 5.17 per cent.

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PIERRE CHEVENARD

CLÉMENT DUVAL
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(Translated by Ralph E. Oesper)

PIERRE (Antoine Jean Sylvestre) Chevenard, one of the foremost French metallurgists, was born on December 31, 1888, at Thizy (Rhône). His ancestors on both sides had been associated with the textile industry, and it was expected that he would follow in their footsteps. However, the death of his father in 1892 changed this plan, and in 1910 he graduated at the head of his class from the École nationale supérieure de Mines at Saint-Étienne (Loire).

His long association with the Société de Commentry-Fourchambault et Decazeville began in 1911 when he was attached as engineer to the laboratory of the steel works at Imphy (Nièvre), one of the oldest in France.[1] In 1912 Chevenard was made departmental head in charge of metallurgical research in this corporation. After World War I he was appointed (1919) professor of metallurgy at the École des Mines at Saint-Étienne and also consulting engineer of the corporation, in charge particularly of tests and research at Imphy. In 1935 he was made scientific director of the firm but with residence in Paris. Finally, since 1950, he has been a director of the Société de Commentry-Fourchambault et Decazeville (and of several other industrial concerns).

His accomplishments during more than 40 years can be classified under four main headings:

(1) Metallurgical researches of an industrial nature, carried out in the plants of the corporation, have been directed particularly at the discovery and improvement of special ferrous alloys. The principal results were alloys resistant to high temperatures, used in chemical industries, and especially in the construction of heat engines and steam turbines; and alloys with a high mechanical resistance at elevated temperatures. The former enabled Georges Claude to carry out (from 1919) the catalytic synthesis of ammonia at high temperatures and under considerable pressure. The latter, more recent, are quite analogous to English alloys, and were used before them in gas turbines and jet propulsion. While extending the researches of Charles Édouard Guillaume, Director of the International Bureau of Weights and Measures,[2] Chevenard, at Imphy, developed "precision metallurgy." This term embraces numerous alloys endowed with exceptional physical, thermal, chemical, and mechanical properties of particular value in metrology, horology, chronometry, telecommunication, and heat measurements.

(2) In more than 200 reports and papers, Chevenard has set down the results of various scientific studies of tempering and drawing the temper of steels; the graphitization of castings; the structural hardening of alloys; the allotropic transformations of alloys and the mechanism of their heat treatment. He has long been interested in transformations not accompanied by change of phase and especially in the anomalies associated with the reversible transformation of ferromagnetic materials and the order-disorder transformation of numerous solid solutions. A whole group of his investigations have dealt with the mechanism and quantitative laws governing humid, dry, and fissuring corrosion of metals and alloys. Another group of studies has been concerned with the hot and cold mechanical properties of alloys, particularly with regard to the laws of flow and internal friction.

(3) The name Chevenard has become known in most circles because his researches have been conducted by means of apparatus designed by him, constructed under his supervision, and subsequently widely used in the scientific and industrial laboratories of France and other countries. These instrumental aids now number more than 150. The most widely used are his dilatometers, thermomagnetometers, and other devices designed for physicochemical analysis; the micromachines for mechanical tests of very small samples of metals; and the precision equipment for determining the flow of metals and internal friction. Last, but not least, are photographing thermobalances giving a visual record, which were developed initially for the study of dry corrosion, and which are now extensively used in automatic analyses and kinetic studies.[3] Many laboratory men are grateful to him for producing equipment which *works*.

(4) Chevenard's educational activities have included courses in metallurgy at the École des Mines de Saint-Étienne (1919–35), at the École supérieure de Fonderie, and at the École des Mines de Paris (1942). However, these were not his only excursions into metallurgical and metallographic instruction. From the time he entered industry he has been concerned with amplifying the education of his immediate collaborators. He instituted, at Imphy in 1932, extension courses which, supplementing the apprenticeship train-

[1] In 1722 Réaumur wrote: "... une de ces petites forges qui est à Imphy dans le Nivernois. Gens sur l'exactitude de qui je puis compter."

[2] J. CHEM. EDUC., **30**, 11 (1953).

[3] DUVAL, C., *Anal. Chem.*, **23**, 1271 (1951); "Inorganic Thermogravimetric Analyses," Elsevier Publishing Co., Amsterdam, 1953.

ing, served to produce groups of advanced workers. This "scientific impregnation" of the plant contributed markedly to the continual evolution of operations tending to yield special products of high quality.

Chevenard was elected to the Académie des Sciences in 1946 in the section "Applications of Science and Industry." He was made *officier* of the Legion of Honor at the instance of the Ministry of National Defense; he is a *chevalier* of the Order of Leopold, and holds the Trasenster Medal. He has been president of various organizations: Société française de Physique; Société française de Metallurgie; Société de l'Industrie minérale; Association technique de Fonderie; Société des Ingenieurs civils de France. At present he is president of the Société française de Minéralogie. He is on the scientific councils of many large schools and is a member of the scientific board of Weights and Measures. He belongs to the committee on inorganic chemistry of the Centre national de la Recherche scientifique, and in this connection he acts as sponsor for young researchers and when need be directs their work.

Extremely modest, very friendly, always ready to oblige his fellow-men, he hides a heart of gold beneath an unassuming appearance.

CHEMICAL RESEARCH IN LIBERAL-ARTS COLLEGES IN 1952

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STUDIES have been made of the contributions from liberal-arts colleges to the *Journal of the American Chemical Society*[1] and the JOURNAL OF CHEMICAL EDUCATION.[2] A broader picture of the research interests of the chemistry departments of these institutions can be drawn from a survey of the periodical *Chemical Abstracts*.

A check of the issues of *Chemical Abstracts* for 1952 shows that 51 liberal-arts colleges had 98 articles abstracted in this key to the world's chemical literature. Thirty-four of these colleges had only one article each, while the eight most active (Amherst, Brooklyn, Carson-Newman, Furman, Mount Holyoke, Oberlin, Richmond, and Wesleyan) account for a total of 45 articles. "The College Blue Book," sixth edition (1950), has been used to determine the liberal-arts status of the colleges. Institutions which grant the Ph.D. degree, or which have professional schools of agriculture, engineering, medicine, pharmacy, etc., are not classed as liberal-arts.

A check of *Chemical Abstracts* for a longer period than one year is desirable, but a record kept for two and one-half years on liberal-arts colleges in the South has not changed the basic picture.[3] Eleven colleges in this section had 24 articles in *Chemical Abstracts* for 1952, and during the preceding 18 months (to the middle of 1950) 12 colleges had 25 articles abstracted; only five colleges (Bethany, Carson-Newman, Florida Southern, Furman, and Texas Lutheran) appear on both the 1952 and 1950–51 lists of abstracts, and they account for a total of 34 articles.

A survey of *Biological Abstracts* for 1951[4] reveals a similar pattern of publication from liberal-arts colleges. Forty-seven colleges contributed 103 1/2 articles abstracted during the year; only 12 institutions appear in both *Biological Abstracts* for 1951 and *Chemical Abstracts* for 1952. This emphasizes the fact that research in liberal-arts colleges depends more upon the interest and initiative of individual faculty members than upon the standing or general reputation of the institutions in academic circles.

Distinction in the training of the leaders of American science is reflected somewhat in the current research interests of liberal-arts colleges. Of the 46 colleges which trained present members of the National Academy of Sciences, nine appear in the 1952 volume of *Chemical Abstracts* (Amherst, College of Wooster, Grinnell, Haverford, Lebanon Valley, Oberlin, Pomona, Trinity, and Wesleyan).[5]

Four of the 22 liberal-arts colleges which trained leaders in the American Chemical Society are also in the 1952 *Chemical Abstracts* (Amherst, Grinnell, Haverford, and Wesleyan).[6]

Five of the 13 colleges which granted bachelor's degrees to leaders of the American Association for the Advancement of Science produced articles in the 1952 *Chemical Abstracts* (College of Wooster, Oberlin, Richmond, Wesleyan, and Wheaton).[7]

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DIAGRAMS RELATING THE PERIODIC TABLE TO GEOCHEMISTRY

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THE periodicity of atomic structures of the chemical elements is illustrated in Figure 1. The figure consists of three parts:

The central part shows the periodicity of atomic volumes by the means of horizontal bars in a column, from hydrogen to uranium. Elements are indicated only by their atomic numbers (Z). The length of the bars is roughly proportional to the atomic radii represented. The values for the radii are taken from the monumental work of Fersman[1] and the more recent one of Rankama.[2] Where more than one reliable measurement is cited, the volume is represented by two bars in line, *e. g.*, the volume of No. 50 (tin), No. 33 (arsenic), No. 15 (phosphorus), and No. 6 (carbon). Atomic volumes for which no reliable references were available were left unrepresented. The visual effect of the central part of the diagram is that of a rough periodicity in the atomic volumes, a periodicity that can be related at a glance to the electronic shell structures on the right and to some features of the nuclear structures on the left. The periodicity of atomic volumes so depicted constitutes a visual supplement to the well-known atomic volume curve of Goldschmidt[3] and, indeed, may be superior to the latter from the teacher's point of view.

The structure of the electronic shells, in the right part of the diagram, is a pictorial representation of the data summarized by Pauling.[4] The ordinate of this part of the diagram is Z, the atomic number from 1 to 92. The seven electronic shells are shown on the abscissa as horizontal bars with their lengths proportional to the number of electrons they contain. Dark lines perpendicular to the bars indicate the electronic levels within the shells. The shells are identified conventionally, from K to Q, and their electron capacity is shown by subscript numbers along the abscissa. The eleven atomic cores, from helium to radon, are noted.

The left part of the diagram shows the atomic weight-Z relationship, with an exaggeration of the

[1] FERSMAN, A. E., "Geochimiia," Onti-Himteoret, Moscow, 1937, Vol. III.

[2] RANKAMA, K., AND T. G. SAHAMA, "Geochemistry," The University of Chicago Press, Chicago, 1950.

[3] GOLDSCHMIDT, V. M., "Über die Raumerfüllung der Atome (Ionen) in Kristallen und über des Wesen der Lithosphäre," *Neues Jahrb. Mineral. Geol. Beilage Bd.*, **57**, 1119 (1928).

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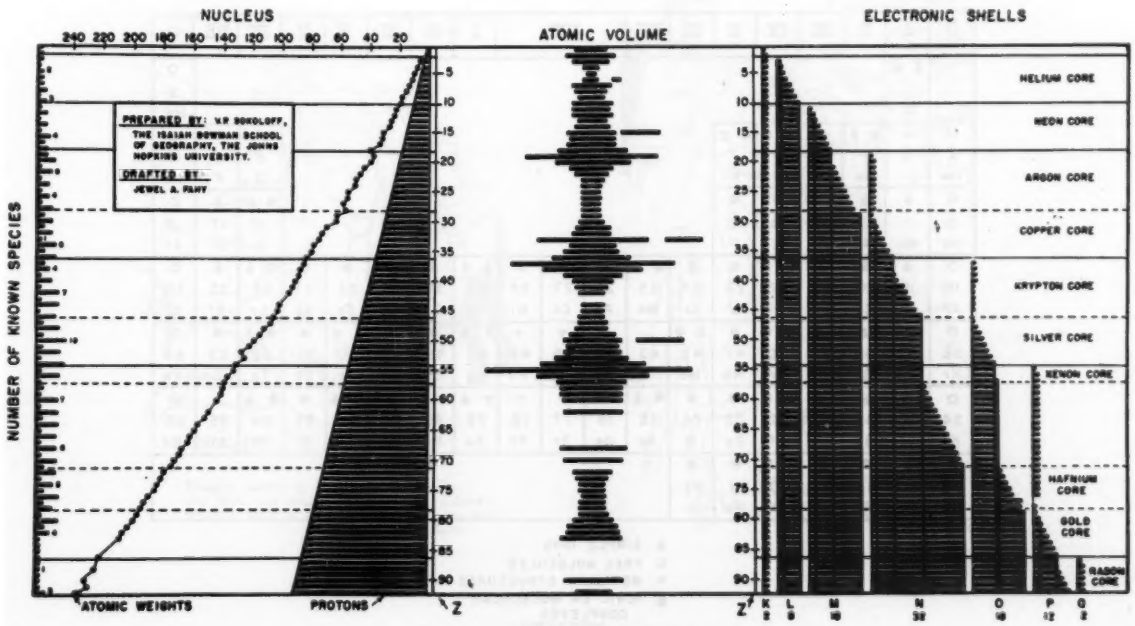

Figure 1. Periodicity of the Elements

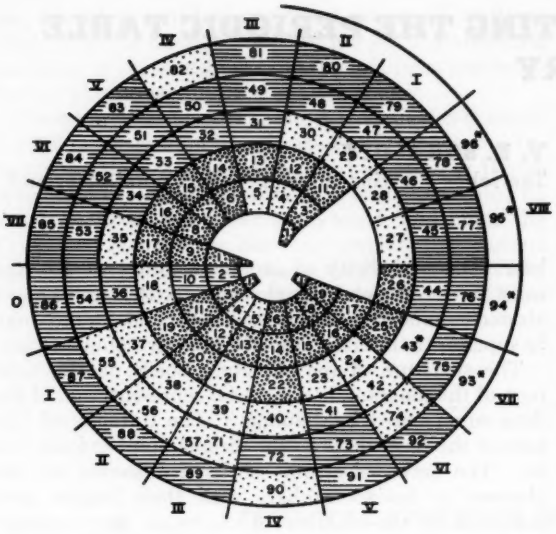
ABUNDANT; 100 TO 10,000 GRAMS PER TON AND HIGHER
MODERATELY ABUNDANT; 100 TO 1 GRAMS PER TON
RELATIVELY SCARCE; 1 TO 0.001 GRAMS PER TON AND LOWER
SO FAR NOT DISCOVERED IN NATURE

Figure 2. Abundance of the Elements

well known irregularities, and the straight line relating Z to the number of protons in the nuclei. The distance between these two lines is indicative of the number of neutrons in the nuclei, in relation to the proton number or Z. Other components of the nuclei are not considered in the diagram. The number of known isotopes is shown approximately, as horizontal bars, with suitable annotations, along the left ordinate, and the atomic weight scale along the upper abscissa.

The relative abundance of chemical elements in the earth's crust in relation to the periodicity of atomic numbers is shown in Figure 2. The atomic numbers are arranged in the form of a spiral, with the unavoidable and useful repetition of the helium and the neon periods, and with the repeated placement of No. 1 (hydrogen). Both the continuity and the periodicity of the atomic structures suggested in Figure 1 are given further emphasis in Figure 2. The irregularly closed beginning and the open end of the spiral are in keeping with the current opinions of the origin and structures of matter and with the possibilities of further expansion of the transuranium series. The spiral arrangement illustrates the importance of both Groups 0 and VIII in the genesis of species of matter somewhat more graphically than the conventional rectangular arrangement.[5]

The shaded background of the atomic numbers indicates the relative abundance of each element. It is shown in three categories, high, medium, and low, as explained in the key. A more detailed breakdown would complicate the diagram unnecessarily and the interested student can be referred for this information to the recent summary of Rankama already cited. Although the diagram is highly generalized, it clearly in-

[5] The spiral arrangement in Figure 2 is crude, in comparison, for example, with the admirably comprehensive and intricate organization of the periodic table in J. Grant's "Hackh's Chemical Dictionary" (The Blakiston Co., Philadelphia, 1944, p. 631). Its crudeness and simplicity, however, permit a rapid grasp of the subject on the part of the student—a response generally not afforded by more elaborate diagrams.

0	I	II	III	IV	V	VI	VII	VIII		I	II	III	IV	V	VI	VII	0
	▲ ● 1 H																○ 2 He
○ 2 He	▲ 3 Li	● ▲ 4 Be	● 5 B	● ○ 6 C	● ○ 7 N										●○▲ 8 O	▲ 9 F	○ 10 Ne
○ 10 Ne	▲ 11 Na	▲ 12 Mg	▲ ● 13 Al	● 14 Si	● 15 P										● ▲ 16 S	▲ 17 Cl	○ 18 Ar
○ 18 Ar	▲ 19 K	▲ 20 Ca	▲ 21 Sc	▲ ● 22 Ti	● 23 V	● 24 Cr	● ▲ 25 Mn	▲ 26 Fe	▲ 27 Co	▲ 28 Ni	▲ + 29 Cu	▲ 30 Zn	▲ 31 Ga	● 32 Ge	● 33 As	● ▲ 34 Se	▲ 35 Br	○ 36 Kr
○ 36 Kr	▲ 37 Rb	▲ 38 Sr	▲ 39 Y	▲ ● 40 Zr	● 41 Nb	▲ ● 42 Mo	43 Tc	+ 44 Ru	+ 45 Rh	+ 46 Pd	+ ▲ 47 Ag	▲ 48 Cd	▲ 49 In	▲ ● 50 Sn	● 51 Sb	● ▲ 52 Te	▲ 53 I	○ 54 Xe
○ 54 Xe	▲ 55 Cs	▲ 56 Ba	▲ 57-71 R.E.	▲ ● 72 Hf	● 73 Ta	● 74 W	● ▲ 75 Re	+ 76 Os	+ 77 Ir	+ 78 Pt	+ ▲ 79 Au	+ ▲ 80 Hg	▲ 81 Tl	+ ▲ 82 Pb	● 83 Bi	● ▲ 84 Po	▲ 85 At	○ 86 Rd
○ 86 Rd	▲ 87 Fr	▲ 88 Ra	▲ 89 Ac	▲ ● 90 Th	● 91 Pa	● 92 U											

▲ SIMPLE IONS
○ FREE MOLECULES
+ METALLIC STRUCTURES
● IONIC OR MOLECULAR COMPLEXES

Figure 3. Forms of Occurrence of Elements in the Earth's Crust

dicates certain anomalous abundances, such as No. 18 (argon) and No. 82 (lead). Plausible reasons for these abundances are found in the well known genetic relationship of argon to K^{40}, and the "magic number" structure of the lead nucleus.

The purpose of Figure 3 is to present an ordered generalization of the most common forms in which the chemical elements occur in the relatively simple environment of the planet's surface. It contains many approximations. The chemical elements are arranged in their periodic sequence, using a modified rectangular form of the periodic table. This arrangement is complementary to those used in Figures 1 and 2 and is well suited to illustrate and to explain zonations and trends in the geochemical behavior of the elements. Four principal forms of the chemical elements are recognized in the table:

(1) Free molecules, the sole form in Group 0 but common also for the elements carbon, nitrogen, and oxygen.

(2) Simple ions, such as H^+, F^-, etc., common for the majority of the elements.

(3) Ionic and molecular complexes, radicals, etc., such as $H_2PO_4^-$, SiO_2, etc., which are equally common.

(4) Metallic structures, found chiefly in Groups VIII and I.

ACKNOWLEDGMENT

I wish to thank Dr. G. F. Carter, Chairman of the Isaiah Bowman School of Geography, for his interest in and encouragement of my Chemical Introduction to Geography of Soils, and Dr. Bentley Glass, Department of Biology, the Johns Hopkins University, for his helpful criticism of the paper.

EDITOR'S NOTE: The following is taken from a letter sent to Dr. Alexander Silverman by the wife of the late Dr. J. W. Mellor. We have permission to reproduce it for our readers who, we feel sure, will be interested in this side light on the life of a great chemist.

"Dr. Mellor was known to his intimate friends as 'that white-haired Peter Pan,' the boy who never grew up. 'Peter Pan in trouble again': a bedroom in the National Liberal Club, London. From that room he was taken to a nursing home and is seen the following morning in 'Il Paradiso.'"

Peter Pan in trouble again — ptomaine poisoning this time. They took him to a private hospital.
L'INFERNO
Ah me!
Almighty Justice! In what store thou heap'st
New pains, new torments as were here endured!
Whatever fault of ours hath brought us to this?
Dante.
He now wants a lot more of the same kind of trouble .... it was worth while!
IL PARADISO
...Know'st thou not thou art in heav'n
And know'st not thou, whatever is in heav'n
Is holy, and that nothing there is done
But is done zealously and well?
Dante.

FILTER PAPER ELECTROPHORESIS

A Biophysical Laboratory Experiment

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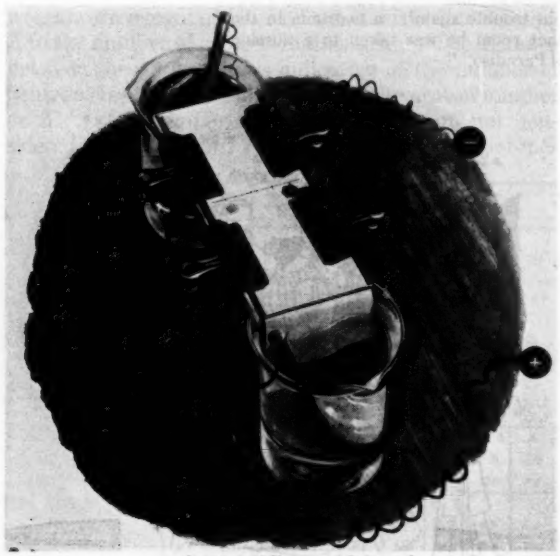
BIOCHEMICAL experiments showing the separation of the several proteins in blood serum have been successful to only a limited degree. Many biochemists have felt that the fractionations are incomplete and that it is questionable whether definite substances are isolated. The ammonium sulfate method of fractional precipitation which is widely used is only moderately satisfactory. An interesting yet very simple technique has been developed using filter paper electrophoresis. Wieland and co-workers (*1*, *2*) in Germany, Durrum (*3*) in this country, and Tiselius and co-workers (*4*, *5*) in Sweden, each independently published reports based on the same theory.

The method is a qualitative one. A high degree of precision is observed when identifying the individual components but it is doubtful that the method as now worked out would give accurate quantitative data. One of the decided advantages of the new technique is the fact that both minute quantities of amino acid mixtures and normal quantities of protein constituents may be separated (*3*). The method is one in which an electrical potential is applied across the ends of a strip of filter paper which has been saturated with either buffer or some other electrolyte solution. At narrowly circumscribed points mixtures of amino acids, peptides, or proteins may be put on the paper. A current is then applied and allowed to run for a period of from three to 15 hours. At the end of this time the positions to which the components have migrated is determined by spraying the paper with, or dipping it into, a developer. Durrum's method (*3*) employs the bromphenol blue dye and is extremely sensitive.



Courtesy of Sharp and Dohme, *Seminar*, Spring, 1953

Figure 1. Apparatus for Filter Paper Electrophoresis

The filter paper strip is shown clamped between glass plates which are resting on the lips of the electrode vessels. Two albumin spots are shown migrating from the line of origin toward the anode.

The author has used the method to demonstrate both electrophoresis and the separation of proteins in blood plasma. The experiment fits well into the physical chemistry laboratory schedule for the second semester. Quite possibly it could also be used in a biochemistry laboratory course. The proposed experiment outline is as follows:

Purpose: The separation of blood serum proteins.

Theory: The electrolytic separation of colloids is one of several methods of separation. Colloidal particles migrate in an electric field but are extremely sensitive to changes in pH. The charge carried by a protein particle is governed by the particular property which is effective in the given environment. In relatively acid solutions protein molecules, being amphoteric, behave as bases and will combine with the free protons, acquiring a positive charge. In alkaline solutions they will transfer protons to the available hydroxyl ions leaving negatively charged particles. These characteristics are the basis upon which electrical separations may be made. When the migration is allowed to proceed through a moist filter paper medium there is sufficient difference in migration rates to bring about a separation of the individual colloidal particles.

Apparatus: Source of 110 or 220 volts d. c., two carbon electrodes, filter paper strips (Schleicher and Schuell #547 or Whatman 3 mm.), two beakers (500 or 1000 ml.), glass plates (rectangular, approximately 4 × 7 in.) and two clamps.

Procedure:

(1) Partially fill two beakers with a buffer solution of pH approximately 7.5.

(2) Cut two strips of filter paper of convenient size to span the distance covered by the rectangular glass plates and to dip into each buffer solution.

(3) Draw a pencil line down the center of one strip of the paper at the point which will be equidistant from the electrodes.

(4) Rub a thin film of silicone grease on one side of each of the two glass plates.

(5) Dip the lined paper strip into the buffer solution and partially dry it by blotting it with the second paper strip.

(6) Set the moistened paper strip on what will be the lower glass plate and line the sides of the paper with silicone grease in order to avoid evaporation during electrophoresis.

(7) Withdraw a sample of serum (0.005 to 0.010 ml.) and apply it at any point on the previously drawn line. A small amount of bromphenol blue added to the serum aids in following the migration of the albumin which binds this dye.

(8) Place the upper glass plate firmly over the paper and clamp tightly with light clamps (Figure 1).

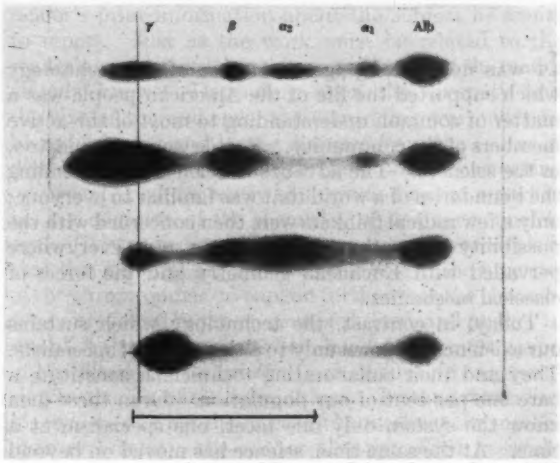
(9) Place the plates on the lips of the electrode vessels with the protruding ends of the paper dipping into the buffer in the vessels.

(10) Apply a voltage of 110 to 220 volts d. c. If a high voltage is used regulate the resistance to avoid heating the paper strips.

(11) Allow the experiment to run from three to 15 hours.

Following the separation remove the paper carefully to avoid smearing; dip it into a one per cent solution of bromphenol blue in ethyl alcohol which has been saturated with mercuric chloride. After two to five minutes pour off the dye solution, which may be used repeatedly, and wash the paper with water which has been slightly acidified with acetic acid. Dry the paper and, if necessary, pass the dried paper through ammonia vapor to bring out the protein spots. Albumin α, α_2, β, and γ appear as a sequence of spots leading out from the pencil line (Figure 2).

The author found that migration is apparent in a matter of 20 minutes at a voltage of 130 v. It is quite probable that a wide variety of filter papers may be used. As with a transference number experiment, the experiment can easily be set up and let run while the students proceed with other work. It requires no watching during the course of the electrophoresis. If samples of normal serum and of pathological serum are available the resulting deviations in pattern are very interesting (Figure 2) and serve to instruct the students as to the practical use of the method in medical diagnosis. Many uses for the method have been proposed. Clinical applications appear to be particularly numerous (*6*). Attention to detail and careful technique are essential to good results and the students find the experiment interesting, challenging, and instructive.



Courtesy of Sharp and Dohme, *Seminar*, Spring, 1953

Figure 2. A Normal Serum (Upper) Contrasted with Three Pathological Sera: Cirrhosis, Nephrosis and Myeloma in Descending Order

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WRITING GENERAL SCIENCE ARTICLES[1]

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It was not so long ago that most of the technology which supported the life of the American people was a matter of common understanding to most of the active members of the community. People were at home, too, in the sciences. The advance of science was extending the boundaries of a world that was familiar to everyone; only a few radical thinkers were then concerned with the possibility that the universe was not everywhere pervaded with Euclidean geometry and the forces of classical mechanics.

Today, in contrast, the technology which sustains our existence is known only to a tiny corps of specialists. They and their collaborating technicians constitute a bare one per cent of our population. Even these men know the system only one facet, one specialism at a time. At the same time, science has moved on beyond the world of daily, common sense experience to open up a universe which "may not only be queerer than we imagine, but queerer than we can imagine."

Thus between technology and science, on the one hand, and popular understanding, on the other, there has developed a gap. It is a gap in the communications of our society which challenges the underlying assumptions of the democratic process. The public issues which preoccupy the political life of America today are heavily conditioned by purely technical considerations, involving realms of information and ideas which are unfamiliar and unknown to the vast majority of the American people. Clearly, if the citizens of our country are to govern themselves wisely, and participate effectively in public discussion and decision, they must acquire a better understanding of science. If we meet this challenge in our schools and colleges, there is hope that the next generation will find itself more comfortably at home in the world of the twentieth and the twenty-first centuries. But for the present, we are confronted with a serious emergency. This emergency gives special importance to the literature of science addressed to general public understanding. And it gives renewed emphasis to the role of the scientist as the teacher as well as the extender of scientific knowledge.

WRITING FOR THE PUBLIC

Needless to say, when the scientist sits down to write an article for the general public he is confronted by a task quite different from the writing of a formal scientific paper. The scientific paper is addressed to readers who share a common interest with the author in his subject matter. Considering that most of his readers will have a practical compulsion to look up the paper, the author's professional colleagues may be described as a captive audience.

They come to the author, furthermore, with a common background of knowledge. He does not have to tell them; they know where his work fits into the scheme of things. They want him to get down to business right away, to give them all the data and a sufficiently precise description of the experiment so they can repeat the work themselves. This leaves little space or time for generalization on what the work means. In fact, such generalization, especially in American scientific literature, has come to be regarded as an impropriety. As the judges of the work, the author's colleagues claim the evaluation of its significance as their prerogative; they do not want the author to tell them what it means.

Finally, there is the well-known barrier to communication represented by language. Precision often requires the use of verbal symbols which have exact definition, known to both author and reader but not necessarily to anyone else. Thus it is no wonder that most formal technical writing proves to be incomprehensible to almost everyone except the author's nearest colleagues in his immediate field of specialization. Sometimes even these initiates must come away with the feeling that the author wrote his paper not to increase their knowledge and understanding, but merely to demonstrate the superiority of his own.

In contrast, an article written for the general reader can have only one purpose: to increase the reader's understanding. Here the relationship of the author and the reader is reversed. The general reader is not obliged to listen. It is up to the writer to tune in on his reader, to find the reader's level of understanding and range of interest. The reader does not necessarily share either the scientist's interest in the work or the background of knowledge which gives it meaning.

RANGE OF INTERESTS

The general reader has, however, other interests to which the work may be—in fact must be—related. These interests are endless in their diversity and present a vast range of opportunity to relate the reader to the author's work. In the popular press of our country we see demonstrated the more obvious lines of popular interest to which scientific work may be tied. There is, for example, the practical interest of the consumer, confronted today with a half dozen alternatives for the satisfaction of almost every material want and desire. There is the emotionally charged interest

[1] Presented as part of a symposium on "What Editors Expect of Authors," at the 123rd Meeting of the American Chemical Society, Los Angeles, April, 1953.

of personal health, involved as it is with the motive of survival. There is the sensation and excitement which attend the limitless possibilities of human experience in the boundless universe of science. High on the list also is human interest in human achievement, the dramatization of the scientist as well as of his work.

These motives are valid enough in their place; they are appropriate to a good deal of what workers in science have to report to their fellow men. At best, they are effective as means of attracting popular interest. At worst, they contribute to further distortion of the popular idea of science as the modern "House of Magic" and to the miscasting of the scientist as the shaman and bringer forth of wonders. We are told that this is "what people want," and this assertion is usually accompanied by the estimate that the public's intelligence is that "of an eight-year-old." The record shows that this estimate comes close to describing the intelligence and responsibility of entirely too many writers, editors, and press agents, but that it falls far short of the true intelligence of the public. In science writing as in other departments of literature, it is the best that endures and ultimately outsells the Grade B productions. Whatever their practical value, the interest motives which are invoked in the science pages of our popular press cannot cover the full range and depth either of public interest or of scientific work.

People are not preoccupied exclusively with the little questions. They are just as often, and more deeply, concerned with the big questions which have troubled the inner life of man ever since the human species attained an inner life. The passion for understanding which motivates the work of the scientist is as widely shared among his fellow men as the faculty of consciousness itself. Science moves forward with little jumps, with small accretions to the total body of knowledge. But its progress is motivated at every step by the larger questions in which all men have a stake.

The enduring books and articles which make up the best of the general literature of science—from Thomas Huxley to Julian Huxley in our own times, from Tyndall and Darwin to Schroedinger, Einstein, and Born—address themselves to this universal interest which all men share in the nature of the physical world and in their own natures. An especially fine example of this straightforward approach to the reader's intelligence is given by Thomas Huxley's "Piece of Chalk." Reversing the now popular method of proceeding from the sublime to the trivial, he leads his readers from the familiar to the farthest reaches of understanding in a half-dozen fields of knowledge. The virtue of this approach to the communication of science is that it conveys not only new information to the reader but also a subjective appreciation and understanding of the spirit and the method of scientific inquiry, which is more important than any amount of information. Writers who address themselves to the highest interest of their readers do justice not only to their reader but to the work of science.

PRESENTING INFORMATION

In brief, it is best to overestimate the intelligence of the reader and therewith to lift the ceiling and broaden the range of discussion. On the other hand, it is essential that the author should underestimate his reader's prior information about the subject he wants to report. Just as the work must be related to the reader's interest, so it must be related to what the reader already knows. Depending upon the diversity and the size of the audience, the connecting trail must be blazed a longer and longer distance from the center of discussion. Take for example the problem confronting one scientist who recently had new findings to report in his investigation of the chemistry of desoxyribonucleic acid. It was necessary for him, of course, to explain that this material plays an essential role in the function of the chromosomes, to explain further that the chromosomes are found in the nucleus of the cell, and further to establish that chromosomes are involved in transmission of hereditary characteristics from generation to generation in the life of all living things. In thus reminding his readers of what they already know about the mechanism of heredity, the author also succeeded in establishing the significance of his work.

Though the author must assume a minimum level of prior information, he need set no upper limit upon the information which the reader can carry away from the article. The reader will be ready to absorb as much new information as will contribute to the increase of his understanding. He will stay with the author in this task so long as the author relates each new unit of information to the central issue with which the article is concerned. The reader wants his facts with relevance.

ORGANIZATION

Turning now to the technical aspects of the subject, the literary compositions of scientists get their lowest marks under the heading of organization. Too often, their articles will be invertebrate recitals of the facts, lacking in structure and synthesis. This may reflect the unfortunate example of the technical paper. But it gives the reader who has the endurance to read the article through an impression that the author himself is not sure what his work means. William Allen Neilson, the late President of Smith College, in his famous Phi Beta Kappa lecture, "The American Scholar Today," before the A.A.A.S. in 1937, declared:

> The ideas most difficult to explain to the layman are often those that are obscure also in the mind of the professional. Even if the attempt is not wholly successful, it is a wholesome and bracing discipline to submit an idea to the test of exposition to the intelligent but ignorant. . . . It can be a powerful agent in clarifying the thought and purifying the style of almost every branch of study.

When the writer really understands what he wants to say, the next step is—briefly and simply—to say it. Having done so, his next step is to relate everything else that he has to say to his major thesis. Like a crystal growing from its nucleus, the subject itself will

most often dictate how the evidence and the data are to be built into the structure of the argument. As he proceeds to unfold his subject in this fashion, the author will find the story developing its own plot and generating the same suspense and tension that carries the reader through the works of fiction. He will find also, as Mr. Neilson promised, that he has learned a great deal more about his subject than he knew when he started.

Thus the contention here is that logical and explicit organization of the article is the first essential to giving it clarity and interest. Given a solid structure, the author can next consider the grace notes. There are, for example, no limits to the forms in which a science story may be cast. These will also tend to come naturally. In preparing the reader with the setting and the background of the subject, the author will almost inevitably find himself engaged in an historical narrative. Since it is well known that narration makes for easy reading, this is all to the good. Similarly, the story of how the work was done will tend to fall into narrative form. This has the advantage of leading the reader through the same inductive development of evidence that brought the author to his conclusion and thus gives him a subjective sense of the rigor of the scientific method, as distinguished from revelation.

The narrative is a reliable device, but it is not the only way to tell a story. The "Piece of Chalk" suggests another classic form, relating the reader's interest in the near and particular to a new understanding of the distant and general. In an article called "Eye and the camera," which we had the privilege of publishing in the *Scientific American* and which will always be one of our favorites, Professor George Wald, of Harvard University, presented a comprehensive picture of our present understanding of the physics and chemistry of the eye in the form of an elaborate metaphor. He sustained the reader's interest from start to finish because there was, when he was through, no principle involved in photography for which he was unable to demonstrate an analogue in the physiology of the eye. Here an entirely obvious metaphor which had been worn out by generations of authors was successfully carried off by one of the finest writers among American scientists. The best advice, however, is the simpler the better. Most often, the story will really tell itself.

LANGUAGE

We come finally to the details. The first that occurs, of course, is the troublesome question of vocabulary. It is not nearly so much of a problem as first appears. In so far as the jargon consists merely in the names of things, the technical term may be easily replaced by familiar, plain English words, perhaps two or three understandable and descriptive words instead of a single unfamiliar one.

It is more difficult to deal with technical terms when they express relationships. But this is only because the relationships themselves are difficult to deal with. We live our lives in terms of one and not more than two variables at a time, and we find that the simple logic of cause and effect gives us a reliable basis for practical day to day decisions. The scientist in his scientific work, by contrast, deals with many variables operating in a state of interdependence with one another. Thus the shorthand word may have to become a paragraph or a chapter in a presentation to the layman, and the presentation may be impossible without the assistance of carefully designed graphic illustration. But we need not make a shibboleth of this language question. Sometimes, as in the wonderful language of geology, with its tarns, drumlins, breccias, moraines, eskers, and monadnocks, the words are part of the fun. They need only to be defined in context as they occur.

The best way to get around this language obstacle, of course, is by using pictures. The graphic arts, whether photographs, diagrams, or tables, can take a good deal of the labor, not to say torture, out of scientific prose. A picture of the unfamiliar thing plainly reduces its mysterious name to the status of a mere label. A diagram of a relationship between two or more variables can reveal their permutations far more explicitly than the most carefully constructed prose. It is so much easier to say "See the picture on page 20" and let the artist do the work for the reader as well as the author.

Another important consideration in scientific writing is the range of quantitative experience with which science deals. Mere numbers fail utterly to convey meaning to the layman in any magnitude exceeding a family bank account on the one hand or a visible fraction of an inch on the other. Here it is best to remember that man is the measure of all things and, with exercise of ingenuity, to find ways of expressing the dimensions of the macrocosm and the microcosm in multiples of human experience with the world in reach of our unaided senses. That is why the writer for the English-speaking lay public is stuck with degrees Fahrenheit, feet, and pounds, no matter how supremely the metric system reigns in science.

CONCLUSION

This suggests the principal advantage of having the scientist tell his own story. The lay writer must inevitably see the work of science from the outside. In his purely reportorial research, he cannot acquire the subjective intimacy with a subject which the scientist develops over years and months of concentrated labor. It is the scientist who has given us our best metaphors for coping with the world that we cannot see. Maxwell's demon, Einstein's wonderful mental experiment with the railroad train, and Nils Bohr's planetary atom have never been improved upon by the lay interpreters of their work. In his dependence on the scientist, in fact, the science writer tends to repeat and belabor the original metaphor out of all recognition. For example, it will take generations of patient re-education to help us recover from Bohr's innocent solar system metaphor and to gain a more accurate feel of the structure of the atom.

Metaphor, vocabulary, and style, however, are com-

paratively minor questions, concerned with local patches of rhetoric. These will take their place and carry their effect only if the structure of the story is properly designed and followed through. Facts and information will be absorbed only to the extent that the total plan of the article sets up attention, interest, and excitement and therewith provides adequate motivation for the intellectual effort which science requires of its readers. There is no literary formula that can take the general literature of science into the field of passive entertainment.

If communication to the general reader is worth this kind of careful effort on the part of the scientific author, the question may well be asked why he should not give the same consideration to his professional readers as well. Perhaps it is not out of order to suggest that the place to begin writing interesting and plainly intelligible science articles is in the journals of science.

AN EASILY CONSTRUCTED MANOMETER

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THE need for a simple, inexpensive manometer for use in the first-year organic chemistry laboratory that can be readily constructed by an unskilled worker prompted us to develop the manometer described below and shown in the accompanying diagram. This manometer can be used for rough measurements in the pressure range of 1 to 110 mm. of mercury, and by suitable obvious modification the range could be extended. It will be recognized that the general design is itself a replica of a type of manometer already widely used. However, the method of construction of our instrument is such that the mercury column can be prepared free of a gas bubble more readily than is the case with some other models. Furthermore, its fabrication from readily available and inexpensive supplies is an added feature.

The inner tube of the manometer is prepared from a 26-cm. length of clean 6-mm. o. d. Pyrex glass tubing. The tube is provided with a seal 4 cm. from one end and the near end is fire-polished. The inner tube is then shrunken and drawn so that an opening of about 0.5 mm. occurs 12.5 cm. from the seal. A piece of No. 24 B & S gage copper wire is a suitable gage for the opening. The open end of the tube nearest the constriction is then flared to provide a wider opening. The tube is held in the vertical position with the flared end up and clean mercury is added until the tube is filled to 1 to 2 cm. above the constriction. The filling is aided by tapping the tube on the desk top. The mercury is then heated carefully in the tube until free of any gases, and finally boiled. The tube is maintained in a vertical position and allowed to cool to room temperature. Starting at the end of the tube nearest the seal, a No. 1 one-hole rubber stopper is worked onto the tube to the proper position as shown in the diagram.

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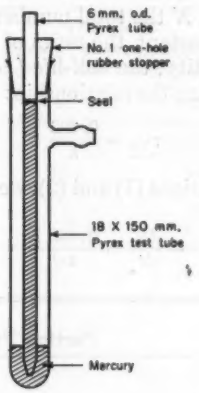
The use of a drop of glycerin as a lubricant for this operation is recommended. The tube is cut at the proper point in the constriction by making a file mark and breaking carefully while the tube is held in a vertical position. It is then carefully turned over and inserted into the test tube which should contain 3 ml. of mercury. It is important that the mercury fill the tip of the inner tube after the tube is broken at the constriction. If this does not occur, the tube can be warmed



until the mercury expands sufficiently to accomplish this and the tube is then immediately inverted into the mercury contained in the test tube as already described. It is also imperative, of course, that no mercury fall from the tube while it is being inverted and set in position in the test tube. A convenient scale, which is not shown in the diagram, is provided by cementing a 15-mm.-wide strip of millimeter cross-section paper along the outside of the test tube. It is helpful if the scale is numbered every 10 mm.

THE RELATIVE CONTRIBUTIONS OF VARIOUS ELEMENTS TO THE EARTH'S RADIOACTIVITY

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THE average student of chemistry, in considering the natural radioactivity of the earth's crust, thinks primarily of the radioactive decay chains originating with the heavy elements uranium and thorium. The existence of long-lived radioactive nuclides among the lighter elements is, of course, well known, but the over-all contribution they make to the earth's natural radioactivity is usually overlooked. The contribution of at least one of these light nuclides is, as will be shown, quite appreciable.

For the purposes of this paper, the degree of radioactivity of a given element will be defined as the number of alpha or beta particles emitted (as the result of the radioactive breakdown of one or more of its component nuclides) per gram atomic weight of element per second. The complicating factor of nuclear isomerism and gamma ray emission will be ignored.

The fundamental equation representing the kinetics of the radioactive decay of a given nuclide is:

$$-\frac{dN}{dt} = \lambda N \qquad (1)$$

where $-(dN/dt)$ represents the number of atoms decaying per second, N the total number of atoms, and λ the radioactive constant, the units of which are sec.$^{-1}$. The familiar quantity, the half-life ($\tau_{1/2}$), can be made use of by introducing the relationship:

$$\tau_{1/2} = \frac{0.693}{\lambda} \qquad (2)$$

Combining equations (1) and (2), we arrive at:

$$-\frac{dN}{dt} = \frac{0.693\,N}{\tau_{1/2}} \qquad (3)$$

where the half-life, of course, must be expressed in seconds.

For a gram atomic weight of an element, N is equal to 6.026×10^{23} and equation (3) can be converted to:

$$-\frac{dN}{dt} = \frac{4.18 \times 10^{23}}{\tau_{1/2}} \qquad (4)$$

In evaluating equation (4), several considerations must be kept in mind.

(1) Where a radioactive nuclide occurs in nature together with one or more stable nuclides of the same element, the value obtained in equation (4) must be multiplied by the fractional occurrence of the radioactive nuclide before it can be made to apply to the element as a whole.

(2) The radioactive potassium nuclide, K^{40}, breaks down in two ways, changing to Ca^{40} by beta-particle emission, and to A^{40} by K-capture. Only the former process (which constitutes 90 per cent of the whole) will be considered here, and the appropriate correction must be made.

(3) In the case of uranium and thorium, three long-lived nuclides are parents of a series of radioactive nuclides, each of which contributes an alpha or beta particle of its own (sometimes both) until a stable nuclide finally results. Three over-all equations can be written to describe the total process:

$$_{92}U^{238} \rightarrow {}_{82}Pb^{206} + 8\alpha + 6\beta$$
$$_{92}U^{235} \rightarrow {}_{82}Pb^{207} + 7\alpha + 4\beta$$
$$_{90}Th^{232} \rightarrow {}_{82}Pb^{208} + 6\alpha + 4\beta$$

Under conditions of radioactive equilibrium each daughter element is breaking down as fast as it is being formed, so that the half-life of the entire chain is equal

TABLE 1
Particle Production of the Naturally Radioactive Elements

Element	*Radioactive nuclide*	*Fractional occurrence of radioactive nuclide*	*Half-life of radioactive nuclide, seconds*	*Particle production per gram atomic weight of element per second*	
				Alpha particles	*Beta particles*
Potassium	K^{40}	0.00011	3.5×10^{16}	...	1.2×10^{3}
Rubidium	Rb^{87}	0.272	1.9×10^{18}	...	6.0×10^{4}
Lanthanum	La^{138}	0.00089	6.3×10^{18}	...	5.9×10
Neodymium	Nd^{150}	0.056	1.6×10^{18}	...	1.5×10^{4}
Samarium	Sm^{152}	0.266	6.3×10^{18}	1.8×10^{4}	
Lutetium	Lu^{176}	0.025	7.6×10^{17}	...	1.4×10^{4}
Rhenium	Re^{187}	0.629	1.3×10^{20}	...	2.0×10^{3}
Bismuth	Bi^{209}	1.00	6.3×10^{24}	6.6×10^{-2}	
Thorium	Th^{232}	1.00	4.4×10^{17}	5.7×10^{6}	3.8×10^{6}
Uranium	U^{235}	0.007	2.8×10^{16}	2.5×10^{7}	1.8×10^{7}
	U^{238}	0.993	1.4×10^{17}		

to that of the long-lived parent member. Since the daughter nuclides occur in nature only as a result of the breakdown of the parent nuclide, the entire chain may, for our purposes, be considered as a unit. Uranium and thorium will therefore, in our calculations, be held responsible for the production of multiple particles for each atom breaking down, in accordance with the equations immediately above.

With all the above in mind, Table 1 can be prepared, the data on the isotopic composition of the elements being obtained from Sullivan's chart[1] and the half-lives in seconds calculated from recent values presented in the literature.[1, 2, 3] Attention is called particularly to the presence of Bi^{209} in the list. This nuclide, long considered stable, has now been reported as alpha-emitting by two separate groups,[4, 5] with the extremely long half-life of 2 to 3×10^{17} years.

Of the ten elements listed in Table 1, only three—potassium, thorium, and uranium—occur in the earth's crust to the extent of more than 10 parts per million, on a weight basis.[6] The other seven elements, even if each is counted as occurring to the extent of 10 parts per million (a very generous figure), can be shown quite simply to account for not more than $^1/_{1000}$ of the natural beta-particle emission in the earth's crust, and not more than $^1/_{100,000}$ of the alpha-particle emission. We may safely concentrate, therefore, on potassium, thorium, and uranium.

From the data in Table 1 and from the occurrence of each of these three elements in the earth's crust,[6] Table 2 can be prepared. From Table 2, the relative contributions of the various elements to the radioactivity of the earth's crust are easily calculated, and the results are shown in Table 3. While uranium is indeed the source of by far the largest part of the earth's natural radioactivity—as might perhaps be expected—it is a bit astonishing to note that the prosaic element potassium shares honors with thorium for second place, and as far as beta-particle production alone is concerned, outstrips thorium considerably.

TABLE 2
Particle Production per Kilogram of the Earth's Crust

Element	*Grams*	*Gram atomic weights*	*Alpha particles produced/sec.*	*Beta particles produced/sec.*
Potassium	26	0.67	..	800
Thorium	0.02	0.000086	490	330
Uranium	0.08	0.00034	8500	6200

The transmutative processes in the earth's crust as a result of radioactivity are not as insignificant as might be expected. The mass of the ten-mile outer layer of the earth (assuming a density of 2.8 and ignoring the oceans) is about 2.3×10^{22} kg. From this and from the data in Table 2 it can be calculated that the earth's crust is losing, *every second*, 9.5 kg. of uranium, 0.74 kg. of thorium, and 1.3 kg. of potassium. On the credit side, the earth's crust is gaining, every second, 8.9 kg. of lead, 1.3 kg. of helium, 1.2 kg. of calcium, and 0.1 kg. of argon. The figures for the two gases are perhaps more impressive if converted into volume at standard temperature and pressure. In these terms, the earth is gaining, every second, 56 liters of argon and over 7200 liters of helium.

TABLE 3
Relative Contributions of Various Elements to the Radioactivity of the Earth's Crust

Element	*% of total alpha particle production*	*% of total beta particle production*	*% of total radioactivity*
Uranium	94.5	84.6	90.1
Thorium	5.5	4.5	5.0
Potassium	....	10.9	4.9
All other elements	< 0.001	< 0.1	< 0.1

[1] Sullivan, W. H., "Trilinear Chart of Nuclear Species," John Wiley & Sons, Inc., New York, 1949.

[2] Curran, S. C., D. Dixon, and H. W. Wilson, *Phys. Rev.*, 84, 151 (1951).

[3] Pringle, R. W., S. Standil, H. W. Taylor, and G. Fryer, *ibid.*, p. 1066.

[4] Faraggi, H., and A. Berthelot, *Compt. rend.*, 232, 2093 (1951).

[5] Riezler, W., and W. Porschen, *Z. Naturforsch.*, 7a, 634 (1952).

[6] Gutenberg, B., Editor, "Internal Constitution of the Earth," 2nd ed., Dover Publications, Inc., New York, 1951, p. 87.

PURIFICATION OF NICKEL WITH CARBONYL

A Demonstration

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THE isolation and purification of nickel by means of carbonyl can be utilized in a lecture demonstration to illustrate gas-solid reactions of oxide reduction, low temperature volatilization of a metal, dissociation of a gas at a slightly higher temperature into a metal and another gas, catalysis, and other chemical operations.

The equipment is simple, the pressure required is atmospheric, temperatures needed are relatively low, the important techniques of the demonstration can be carried out in a short space of time, and the experiment has the added interest of reproducing on a laboratory scale a commercial process by which a considerable proportion of the world's nickel is refined. The only drawback to the demonstration, the high toxicity of nickel carbonyl, which necessitates reasonable care in carrying out the experiment, can be put to good account by the lecturer when illustrating the hazards often encountered in industrial practice and the safety precautions which should early become a part of students' thinking.

When dry carbon monoxide is passed over reduced impure nickel in a finely divided form at a temperature of 45°C. a volatile gas, nickel carbonyl, $Ni(CO)_4$, is formed. At a higher temperature, around 240°C., nickel carbonyl is decomposed into pure metallic nickel and carbon monoxide. This is the basis of the Mond or carbonyl process of nickel refining, which has been in operation in Britain for over fifty years. The other important commercial process of nickel refining, practiced in Canada, is electrolytic.

The starting product for the carbonyl process is an impure nickel oxide, obtained by various concentrating and smelting practices from the nickel sulfide ores of Ontario. Other metals, with the exception of iron, do not form carbonyls at a low temperature and at atmospheric pressure. A very small amount of iron carbonyl is formed under these conditions, but if the quantity of iron in the starting material is low, as can be readily achieved by ordinary metallurgical separations, the iron in nickel metal obtained by the carbonyl process is insignificant.

The apparatus for this demonstration consists of reducer, volatilizer, and decomposer. Spread 1 g. of technical nickel oxide, with which has been thoroughly mixed 0.005 g. iron pyrites, along a length of several inches in a silica combustion tube within loosely fitting asbestos plugs and reduce with a slow stream of hydrogen, about 2 liters per hour, for an hour at 600–700°C. With the hydrogen still passing through the tube, withdraw the latter from the furnace and cool rapidly by pouring water over it. When the tube has reached 45–50°C. insert it into a volatilizer consisting of an air oven or cardboard box heated to 42–48°C., and connect the exit end to a 10-mm. glass tube about 18 in. long inserted into another air oven or low-temperature furnace regulated to 220–240°C. The latter serves as the decomposer.

With appropriate manipulation to ensure no exposure of the reduced nickel to air during the reduction, cooling and insertion of the tube into the volatilizer, replace the stream of hydrogen with one of dry carbon monoxide at a rate of about 2 liters per hour. Light the carbon monoxide emerging from the exit end of the glass tube in the decomposer, and always ensure that this is burning by placing under it a small burner or alcohol lamp. The nickel carbonyl gas formed in the volatilizer will be dissociated in the decomposer at 240°C. and will deposit metallic nickel on the walls of the glass tube. Traces of nickel carbonyl may appear at the exit end of the decomposer if the flow rate of carbon monoxide is too great, and will impart a white tinge to the carbon monoxide flame. Since nickel carbonyl is about five times as toxic as carbon monoxide, a flame must always be kept burning at the exit end of the decomposer to dissociate any residual nickel carbonyl, and all gas connections from the volatilizer onward must be absolutely tight.

The rate of reaction is such that usually many hours are required for its completion, but a nickel mirror appears on the walls of the decomposer tube in a few minutes, even with a very low carbon monoxide flow. A high rate of flow of carbon monoxide is to be avoided as it may cause a rapid deposit of nickel and possible blockage of the tube, or a loss of nickel carbonyl at the exit end of the decomposer. Since cobalt does not form a carbonyl under these conditions, this process serves to separate nickel from cobalt very effectively. The addition of iron pyrite to the initial charge in the reducer is for the purpose of providing a small quantity of sulfur, which is apparently a catalyst in the production of nickel carbonyl. The latter is only formed from metallic nickel, and cannot originate from the oxide, sulfide, or silicate forms of nickel unless they are first reduced.

THE BEGINNINGS OF THE DOCTRINE OF CHEMICAL AFFINITY

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THE dawning of Greek natural philosophy also presaged the outlines of the future science of chemistry: the *Panta rhei* of Heraclitus; the eternally moving atom world of Democritus; the four elements of Empedocles, kept in constant motion and regroupings by "love and hate"—these all foreshadowed and molded the coming theories of chemical affinity and dynamic equilibrium. When Aristotle (384–322 B.C.) attempted[1] a systematization of the then known chemical materials, he dealt not only with the familiar elements (gold, silver, copper, tin, lead, iron) but also, and for the first time, with a unique silvery liquid metal, to which he accordingly ascribed a certain water content. His pupil Theophrastus (*ca.* 372–287 B.C.) described the preparation of this "liquid silver" from cinnabar,[2] by mixing the latter (HgS) in a copper vessel. The famous physician Dioscorides (first century A.D.) described this metal in more detail and called it "hygragyrum." Practical use was made of it for fire gilding because it readily combines with gold, and according to Vitruvius (born *ca.* 80 B.C.) it was employed to recover gold from ornamented garments. Dioscorides also discussed the preparation of pure mercury by distillation and sublimation.

As *argentum vivum* (= quicksilver) or *mercurius*, this puzzling metal played an exceptional role in alchemical-chemical theories and practices for more than a thousand years, beginning in the early Middle Ages. From the standpoint of preparative chemistry, this earliest production of a metal by a wet method is notable, particularly because it utilized a typical ion-exchange reaction, *i. e.*, the substitution of copper for mercury. Likewise, the metal was used in the first technical synthesis of a natural mineral product; as early as 800 A.D. mercury sulfide (cinnabar) was prepared by sublimation of a mixture of mercury and sulfur.[3] Later these elements were promoted to the rank of primary materials of compounds; as *elementa* or *principia naturalis* they became dominant, especially through the Geber works, which were shifted back to the eighth century. These texts, containing the earliest affinity series of the elements, referred on the one hand to mercury as the most ancient liquid solvent for metals, and on the other to sulfur.

Before discussing these historic contents of the Geber texts in greater detail it would be well to look into the history of Geber himself. What do the historians teach about him? Geber, "the greatest and most sagacious philosopher and king of the Arabs,"[4] "Father of Alchemy," lived around 750 in Cordova and discovered nitric acid, alcohol, many salts, operations, etc.[5] "The most famous Arabian alchemist and chemist was (about 776) Abu-Musa-Jâbir-ibn-Hajjân...who was held to be the real author of many texts, which later...were ascribed to a nebulous 'Geber'."[6]

On the basis of the studies by Berthelot (1888 and later), by E. J. Holmyard (1926), and particularly by J. Ruska and P. Krauss (1923–30), G. Lockemann[7] came to the conclusion that the Latin Geber texts did not originate in the eighth century but more probably at the end of the thirteenth century, and that the noted eighth-century chemist Jâbir[8] is a legendary personality, the texts ascribed to him being forgeries due to an Arabic religious sect of a later date.

ORIGIN OF GEBER'S TEXTS[9]

The following conclusions of chemical historical interest may be drawn from the nomenclature employed by Geber:

(1) Geber was acquainted with the preparation of alcohol or *aqua vitae;* he recommends it for the solution of metal salts. However, *aqua vitae* was not known until the middle of the twelfth century, and it was more generally available only after Alderotti (*ca.* 1250) had developed distillation with a cooling head.

(2) Geber uses—as familiar—the term and concept *affinitas.* However, Albertus Magnus (1193–1280) is held to be the creator of this concept in his "De mineralibus mundi."

(3) Geber also uses the term *vitriol* (iron vitriol,

[1] ARISTOTLE, "Meteorologia," III, IV.

[2] THEOPHRASTUS, "Stones." In his "Perfumes" he also describes the touchstone and a water bath.

[3] Directions for this preparation are found in the monastic recipe books, which go back to the eighth century, *e. g.*, in "Compositiones ad tinguenda musiva."

[4] GMELIN, J. FR., "Geschichte der Chemie," 1797, Vol. I.

[5] SCHELENZ, H., "Geschichte der Pharmazie," 1904.

[6] DAMPIER, W. C., "History of Science," 1948.

[7] LOCKEMANN, G., "Geschichte der Chemie," 1950, Vol. I, p. 35.

[8] See, for example, OESPER, R., AND J. RUSKA, J. CHEM. EDUC., 6, 1266 (1929).

[9] DARMSTAEDTER, E., "Die Alchemie des Geber," Berlin, 1922. The five Geber books (in the Darmstaedter translation) are: I. "Summa perfectionis magisterii," pp. 19–95. II. "Liber de investigatione perfectionis," pp. 95–103. III. "Liber de inventione veritas sive perfectionis," pp. 103–14. Here, on pages 113–14, is given in terms of quantities, the recipe which had already been given qualitatively on page 111 for the preparation of nitric acid and aqua regia. IV. "Liber fornacum," pp. 114–25. V. "Testamentum Geberi," pp. 125–30; obviously interpolated.

Roman vitriol, and red vitriol), which is likewise credited to Albertus Magnus.

(4) Similarly, the terms *amalgam* and *amalgamation* are commonplace with Geber. The coinage of this word—in place of the *malagma* of the Greek alchemists—is ascribed to Thomas Aquinas (1226–74).

From Geber's acquaintance with and use of these terms it follows that he composed his texts around 1250 at the earliest. The obvious dependence on the clerical scholars and authorities makes it quite certain that "Geber" stood quite close to these circles. This assumption is further supported by the fact that the earliest Geber manuscripts are found in Munich (thirteenth century) and in St. Gallen (fourteenth century), which may mean that these writings were produced (perhaps as monastic activities) in the region north of the Alps. The likening of sublimed mercuric chloride to "pure white and glistening snow" suggests a colder climate.[10]

If, on the other hand, a study is made of the materials included in the Geber texts, interest attaches to the origin of the substances mercury and *tutia* (tutty), *i. e.*, zinc oxide or calamine, which are mentioned frequently. The designation of weights and magnitudes is also a characteristic feature. For example, "Take one pound of the purest silver, eight pounds of mercury. . ." or, for the preparation of sublimate of mercury, "Take of it [*i. e.*, mercury] one pound, of red vitriol two pounds, of ordinary salt one-half pound, two pounds of calcined alum, and of saltpeter one-quarter pound, mix the whole, and sublime. . ." The processing of such considerable quantities in single batches or the use of sublimation vessels (*aludels*) a foot or more in length suggests operations on a manufacturing scale. Likewise, the instruction to carry out the calcination of salts and metals (copper, lead, iron, tin) in a glassmaker's furnace, potter's furnace, or reverberatory furnace testifies to a close relation to technical operations. With regard to *tutia*,[11] through which "copper is colored a beautiful yellow," it is stated that its fumes "deposit on the walls of foundries," a reference to brass works and casting houses. It may thus be deduced that the author (or more likely authors) of the Geber texts wrote not solely concerning personal experimental findings and discoveries, but also reported on their practical experiences in metal foundries and manufacturing chemical works. In the thirteenth century the central European area contained many mines and smelting plants which were under the patronage of secular and clerical princes, *e. g.*, in the Upper Rhine district (Baden), in the Harz (Goslar), in the Meissen region, in the Saxon-Bohemian Erzgebirge, in the vicinity of Salzburg, and in the Tyrol. Here were produced and processed gold, silver, copper, lead, mercury (cinnabar), iron (sulfur and iron vitriol from pyrites), tin (discovered about 1150 in Saxony and Bohemia), zinc oxide (for making brass = *lattung; laiton*, Fr.; *latúnj*, Russ.), and arsenic (white copper bronzes). Geber repeatedly mentions the salt, copper vitriol, under the name *cuperosa*. The usual etymological interpretation of this name is *cupri rosa, cupri erosum, cupri erosum substantia*, or *cuprum erosum*. However, the German term *Kupferwasser* is also used.[12] With regard to the origin of this term (and therefore of *cuperosa*, = *couperose*, Fr.; *copparosa*, Ital.; *copperas*, Eng.; *coúporós*, Russ.), it is worth noting what Geber wrote: "If one looks around in the ore deposits of these metals (iron and copper), it is found that an alum-like substance drips from them, which has been formed from them and deposits on them" (*i. e.*, crystals of iron and copper vitriol). It should be stressed that the Arabian alchemists used the term *zāg* or *zādj* for the vitriols in general. It is likewise important and in conflict with the hypothesis of an Arabian origin of Geber that the volatile salt *nuschadir*, which was so highly esteemed by the Arabs and given so many cryptic names, is met for the first time in Geber as *sal ammoniacum*. Furthermore, there is a complete absence of references to Arabic writers and sources in the Geber texts, and, moreover, there is no mention by the Arabs, as late as 1300, of the discovery of the mineral acids.

These facts lead to the following conclusions:

(1) The name Geber has been historically well established and sanctioned by the succeeding generations since the publication in 1481 (?) of the incunabulum "Summa perfectionis magisterii."

(2) The Latin manuscript, from the thirteenth century, is a textlike composition, produced after 1250, probably in the central European area, by a technically experienced chemist who had made independent researches, and containing references to the Geber texts II, III, and IV, and also to the "sharp waters."

(3) These Geber texts are original texts with respect to the facts they contain, and their style has nothing in common with the five-centuries-older Arabic texts of one Jâbir ibn Hajjân, who supposedly wrote at Baghdad around 750.

(4) The discriminatory appellation "pseudo-Geber," which arose from a false appraisal of Arabic alchemy and the outstanding achievements of Geber, should be expunged from the history of civilization and chemistry.[13] In fact, the name pseudo-Geber is much more

[10] Consideration should also be given here to the early technical employment of nitric acid as parting liquid in the Harz region (see footnote 22) and also of the production in this region of the "Probierbüchlein" (footnote 23), which indicates the existence of a long tradition.

[11] The naming of an individual metal as "zinc" occurs for the first time (*ca.* 1525) in Paracelsus (Sudhoff Edition, Vol. III, 49, 58). This author returns to the metal (1538) and states that zinc is found only in Carinthia (Sudhoff, XI, 13, 105). Paracelsus also mentions the metals cobalt, bismuth, arsenic, and antimony, and thus breaks through the ancient doctrine of seven planets and seven metals.

[12] It may be recalled that Isaac Newton (1643–1727) requested a friend, who was about to go to Germany, to "obtain particulars of a *water* in a mine, which had the property of changing iron into copper." PARTINGTON, J. B., *Chymia*, **1**, 110 (1948).

[13] For example, MEYER, E. v., "Geschichte der Chemie," 1914, Vol. 33, p. 49.

applicable to Jâbir ibn Hajjân, who became "the foremost Arabian chemist" only after he had been credited with Geber's accomplishments.[14]

CHEMICAL CONTRIBUTIONS OF GEBER'S TEXTS

The Geber texts are intended to "teach the whole content of the art" (*i. e.*, mastery of the ennoblement of metals); they therefore form a kind of textbook of metal chemistry, communicating tested procedures, personal experiences and discoveries, and inspiring to further studies. The disciple and searcher should have three things at his command: patience,[15] time, and proper equipment; "he should strive to discover knowledge through his own diligent labor, not through studying books but by studying Nature." It should be noted that "we cannot imitate Nature in the chief things, but we can come close to her artificially by producing the intermediate links or products." The following operations serve in this connection: sublimation descension, distillation,[16] calcination, dissolution, coagulation (*i. e.*, crystallization), fixation (stabilization), and ceration (softening). The purpose of these operations was to remove the "superfluous" (earthy matter, moisture, combustibles) and to supply the "lacking" (purest mercury and sulfur). Because these latter constitute the "matter of the metals" and also the "substance of the philosopher's stone," they are, in their smallest particles, combinations of air, water, and fire. These prime materials—mercury and sulfur—are spiritous in nature, *i. e.*, they are volatile materials. In particular, sulfur and arsenic, as combustible materials, are of "fatty" or "oily" origin, a viewpoint also championed by Paracelsus, Becher, and Stahl. The emphasis on "calcination" for the "purification of metals" raised a question that was pursued through many centuries and was not answered satisfactorily until Lavoisier announced his oxygen theory.

The Geber methodology has been given here in some detail in order to point up the vast difference between his so-called "alchemy" and that of the real alchemists, the latter being characterized by its emphasis on allegorical symbolic allusions and repetitions.[17] Geber's chief aim was to produce pure materials and the products of their union. Like a conscientious technical man he described the materials, operations, and end products in a clear and factual manner, and definitely prescribed the necessity of closely checking the latter to discover whether "the magisterium of ennoblement has really succeeded." As a practical goal Geber limited himself to the refinement of metals through the formation of alloys, surface layers, etc., without slipping into the biological realm of the "elixir of life." On the theoretical side Geber rejected any influence of a particular "conjunction of the heavenly bodies" on the artificial ennobling of metals, and, since he was acquainted with the "destruction" of gold, he conversely held that its artificial synthesis in a shortened time was not impossible.

Geber provides a full measure of individual facts and observations and also a considerable body of fundamental insights. The following are worth special mention: The purification of substances is increased by repeating the operation of coagulation (*i. e.*, crystallization). Solubility is the mark of the salts, alums, and other substances.[18] There are still other salts, *e. g.*, vitriols, borax, etc. Under the designation *sal ammoniacum* (or *armoniacum*), Geber for the first time presented a volatile salt, which the great physician Rāzi (tenth century) had characterized as stony, mineral-volcanic, under the name *nūšādir* (imperishable fire). Geber gives his own method of preparation from five parts human urine, one of perspiration, one of ordinary salt, one-half of wood soot. After prolonged boiling the residue is sublimed and the pure product is then obtained by dissolving the sublimate, crystallizing, and again subliming. Geber's term *sal ammoniac* has remained firmly fixed in the occidental literature, while the Persian-Oriental *nūšādir* survives in the Russian *nāsātýr*.

A *sal tartari*, an *oleum tartari* and *sal alkali* (potassium carbonate and hydroxide) were obtained from distilled wine (as *tartarus*). It should be noted that *tartarus* and *alkali* were familiar terms in chemistry in Geber's time. He was the first to recommend the use of *spirit of wine* as solvent for "metal salts." He prepared the metal oxides as calces by calcining the metals or by oxidation with saltpeter. For instance, he pre-

[14] Some Latin texts, derived from Byzantine-Greek sources, also circulated through Europe along with the genuine Arabic alchemical Jâbir texts stemming from the eighth or ninth century. These chemical-technical trade manuals were used in manuscript form in monastery laboratories. Typical instances were: "Compositiones ad tingenda musiva," (mixtures for coloring mosaics) and "Mappae clavicula" (key to dyeing). Their historical importance is indicated by the results of a recent census, which disclosed the existence of more than 100 manuscripts of this kind in occidental libraries. See JOHNSON, R. P., "Compositiones variae," Urbana, Ill., 1939.

[15] Geber counsels: "Have patience and allow yourselves time, because haste is a thing of Satan." The Arabs have a similar proverb, likewise the Finns.

[16] Geber was not acquainted with retorts made of a single piece. He distilled from the two-piece apparatus consisting of a distilling vessel, the *curcubit* or *curbia*, and an upper sealed-on alembic (Gr. *ambix*, helmet) provided with an outlet tube. "Both should be made of glass." The *aludel* and the *ampulla* were both sublimation vessels. All of these were not of Arabic origin. Geber recommends *repeated* (fractional) distillation, whereas the famous Al-Kindi (Baghdad, tenth century) practiced a primitive distillation and for sublimation used a tirās (beaker) çovered with a gām (bowl).

[17] The affinity of sulfur and mercury is tentatively explored by Geber from the standpoint of quantity relationships. This is in sharp contrast to the grandiloquent concept (male and female principle) of the alchemists. The far superior language and objectives of Geber make the appellation "alchemy of Geber" seem out-moded and incorrect. The Geber texts deal with the "art of refining metals."

[18] "All calcined bodies have a nature similar to that of salts and alums." They dissolve in hot water or in distilled vinegar or a similar (acidic) substance, *i. e.*, they go over into salts.

pared "red, glittering" mercuric oxide by sublimation (*i. e.*, strong heating) of one part mercury, two parts red vitriol (basic ferric sulfate), and one part saltpeter. Similarly, he carried out an indirect chlorination when he prepared corrosive sublimate by the sublimation of one part mercury, two parts red vitriol, one part calcined lime, one-quarter part saltpeter, and one-half part common salt, or lead chloride and stannous chloride, by heating the respective calces with *sal ammoniac*. Cinnabar (mercuric sulfide) was prepared by the direct sublimation of mercury and sulfur mixtures. He prepared alkali sulfides from sulfur and caustic lyes. On the addition of "good vinegar," the clear filtrate yields a liquid "like milk," *i. e.*, milk of sulfur (colloidal sulfur). He distinguished clearly between *plumbum nigrum* (lead) and *plumbum album* (tin). He states: "When iron and copper are placed in sharp acid liquors, many parts of them dissolve *per ebullitionem*" (*i. e.*, with evolution of gas)—probably the earliest authoritative report of the production of hydrogen, and far prior to Paracelsus, Turquet de Mayerne (1563–1655), etc. Dry distillation of salts and salt mixtures led him to the discovery of mineral acids: sulfuric acid (or sulfur trioxide) by sublimation of vitriol or *cuperosa;* nitric acid or *aqua dissolutiva* (parting acid) from one pound vitriol, one-half pound saltpeter, and one-quarter pound alum. The resulting liquor "becomes still sharper if you dissolve one-quarter pound *sal ammoniac* with it." "The liquor then dissolves gold, sulfur, and silver," in other terms, *aqua regia* has been formed and sulfuric acid has been produced from sulfur. By dissolving silver in "its solvent, evaporating, and allowing to stand in a cool place, deliquescent crystals separate"—the earliest preparation of crystalline silver nitrate.

The discovery of the mineral acids by the unknown Geber can be ranked next to the discovery of fire, also by an unknown. It was only through the mineral acids that there became possible a chemical working technique by the wet method and at relatively low temperatures, and also a methodical synthesis of inorganic compounds (salts). The rule, *Corpora non agunt nisi soluta*, developed for chemical practice, and this solution chemistry of the salts gave rise suddenly, after five centuries, to a stoichiometry, in the hands of J. B. Richter (1792).[19]

THE DOCTRINE OF CHEMICAL AFFINITY

In addition to Geber's outstanding contributions to preparative chemistry, two other fundamentally important accomplishments should be noted:

(1) Gold and silver were held to be the most perfect (noblest) metals and to them he applied the rule which he had gained from actual experience: "By repeated calcination and reduction, the perfect metals lose none of the qualities of their perfection, such as color, weight, luster, and mass, no matter how often these operations are repeated."[20] In this experimental finding we have the earliest statement of the law of the conservation of mass and of the elemental type of particular materials. This discovery has usually been credited to J. B. van Helmont (1577–1644).

(2) Mercury and sulfur were denoted by Geber as being the prime materials of the metals and hence he called them *elementa* or *principia*. An excess of sulfur (*sulfureitas superfluxa*) produces the imperfection of the metals and its removal is a chief part of the "preparation" and "ennoblement." Albertus Magnus (1193–1280) had taught: "Sulfur blackens silver and in general burns the metals because of its affinity for these materials."[21] Although Geber emphasizes this affinity of sulfur he also writes: "Mercury holds related materials tightly and repels the others," and, "It unites readily with the metals which are of similar nature to itself." Here we have the doctrine of *similia similibus*, namely, that there is a natural affinity for that which is like or similar. Geber then develops this topic and for the first time attempts to measure such affinity. For the seven classical metals he determined: (*a*) the speed and the gradation of their union with mercury, and (*b*) the relative ease of combustibility of the metals with sulfur (*i. e.*, sulfide formation). The following affinity series resulted: "Tin and silver are most closely related to gold in kind." With respect to weight and soundlessness, lead is closest, while copper is closest with regard to color; tin is nobler than lead; "the perfect metals have much quicksilver substance and consequently gladly unite with mercury. . . . It is apparent how easily silver and gold take up mercury." "Mercury combines readily with three metals, namely, lead, tin, and gold. With silver with somewhat more difficulty than with gold. It combines with iron only if some device is employed." Therefore, the affinity of the metals for mercury (amalgamation) is displayed in the sense of their noble nature in the decreasing order:

gold > tin > lead > silver > copper > iron

In reverse of the preceding, the behavior of the metals toward sulfur will be oriented in accord with their degrees of imperfection (or non-noble nature), because, (*a*) "those metals are the most imperfect which contain much sulfur substance" and (*b*) the affinity between substances runs parallel to their similarity of nature (or composition). Geber then confirmed that, "of all the metals, gold is the least burned by sulfur. Tin burns more easily, silver still more readily, then lead, still more easily copper, and iron is burned most easily of all by the oily substance of sulfur." The increasing order of this combustibility with sulfur (sulfide formation) and imperfection is consequently:

gold < tin < silver < lead < copper < iron

[19] See OESPER, R. E., AND L. DARMSTAEDTER, J. CHEM. EDUC., **5**, 785 (1928).

[20] See also ALBERTUS MAGNUS, "De coelo," III, tr. 2, where similar ideas are expressed.

[21] ALBERTUS MAGNUS, "De rebus metallicus et mineralibus," Vol. V.

A third idea announced by Geber was: "The metals are more or less easily burned (oxidized) during their calcination or cementation (by fire) according to whether they contain more or less of combustible sulfur." Their combustibility, *i. e.*, oxide formation, follows the same order as sulfur content. "Since, of all the metals, gold contains the least sulfur, it burns the least in fire. After gold, silver contains the least sulfur; it correspondingly endures strong fire less well than gold. Still less so copper, because it contains more sulfur than gold and silver. . .Tin withstands strong fire still less than copper (though it contains less sulfur). . . Lead contains still more earth and sulfur substance" and so burns more easily than the other metals. "Likewise, iron burns in accord with its innate combustible nature."

The following order was thus established for the relative affinity for the calx-forming principle (*i. e.*, oxygen), in which the tendency to form oxides increases from left to right:

gold < silver < copper < tin < lead < iron

These Geber gradations are the earliest affinity series. Though obviously, and in keeping with the period, they are purely qualitative in character, they nevertheless are of historical importance because they injected a new scientific problem into the practical chemistry of the day, and in their further development they led to a quantitative theory of affinity.

The first of Geber's prime discoveries to find immediate application in chemical practice was *aqua dissolutiva* also known as "sharp or strong water." As *aqua separationis* (parting liquor) it was used at Goslar around 1433 to separate gold from silver and in the determination of gold in argentiferous alloys. J. J. Becher (1635–82) records the following episode, which certainly deserves to be critically examined:[22]

The Germans doubtless discovered the parting liquor
Because of this they were held captive at Venice
And this was the Venetian gold-making
Whereby they separated gold from Spanish silver

In any event, the use of mineral acids in metallurgy became well established. Furthermore, the Geber law of conservation was supported by Thomas Norton, who in his "Crede mihi" or "Ordinale" (1477) stated that "all metals, even though dissolved in sharp waters, remain in *sua integra compositione.*"

FROM PARACELSUS TO THE PRESENT

The part played around 1500 by *aqua fortis* and *aqua regia* in metal and mining chemistry can be seen by an examination of the contemporary "Probierbüchlein"[23] which was published at Magdeburg and Wolfenbüttel in 1510 and 1520. This manual of assaying gives precise directions for: (1) Dissolving silver in *aqua fortis* and then precipitating it as chloride by adding sodium chloride solution, and then recovering pure silver from the precipitate by the lead assay. ("You will again have as much silver as before," an additional confirmation of the Geber conservation principle.) (2) Separating gold from silver by means of *aqua fortis*, separation of the undissolved gold powder from the silver solution, and precipitation of the silver by either pouring the solution into a copper vessel, the silver being deposited on the bottom, or by adding a little copper.

The use of mineral acids and their artificially prepared salts in medicine was popularized by Paracelsus (1493–1541). He also introduced *salt* as the third principle in the "Tria prima." Salt and chemistry by the wet method with the three elements, *mercurius*, *sulfur*, and *sal*, now began their triumphal march.

Paracelsus had likewise received his chemical training in metal foundries and laboratories, and he, like Geber, was intensely interested in mercury and its affinity with other metals. He wrote that *mercurius vivus* amalgamates with the metals and unites completely—however, with one much more readily than with the other, according to which metal in its nature is more closely related and therefore more noble. Consequently, fine gold is followed by silver, lead is third, tin fourth, copper fifth, and iron comes last[24] because "*mercurius vivus* is a mother of all metals."[25] Though he probably worked with purer metals and had wider experience, Paracelsus repeats here the Geber series of the amalgamation speeds of the metals, beginning with the greatest, that of gold:

gold > silver > lead > tin > copper > iron

The affinity problem was considered and utilized from still another angle in metallurgical practice. The basic consideration was that different dynamic effects or intensities must also be proportional to these differing degrees of affinity. Accordingly, a "stronger" metal must displace a "weaker" metal from a compound. In fact, was not the winning of mercury from cinnabar by means of copper, in the presence of vinegar (a process used as early as the fourth century B.C. by Theophrastus), a displacement reaction of this kind? Similarly, the precipitation of dissolved silver by metallic copper as described in the "Probierbüchlein" was another instance of this type of reaction. The alchemists were well acquainted with the fact that iron becomes coated with copper when immersed in a solution of copper vitriol and they cited this effect as a proof of transmutation. It was not until 1603 that Guibert (1540–1620) showed that this was again a displacement of copper by iron.[26] The same conclusion was reached independently by Angelus Sala (1576–1637), who[27] set

[22] Becher, J. J., "Närrische Weisheit und weise Narrheit," 1682. The question is still unsolved as to whether the "Germans" discovered the parting liquor or whether they were the first to practice the parting of silver from gold-silver alloys.

[23] "Bergwerk und Probierbüchlein," ascribed to U. R. von Kalbe. Translated by A. Grünhalt, Sisco and Cyril Stanley Smith, New York, 1949.

[24] Paracelsus, "Werke" (Sudhoff edition), Munich, 1925, Vol. II, p. 365.

[25] *Ibid.*, Vol. XI, p. 318.

[26] Guibert, Nicolas, "Alchymia ratione et experientia." See *Chymia*, 2, 115 (1949).

[27] Sala, Angelus, "Anatomica vitrioli," Leyden, 1609.

up an order for the stepwise displacement (precipitation) of dissolved metals by the free precipitating metals, a series in which each preceding metal precipitates the following one:

iron *ppts.* copper *ppts.* silver *ppts.* gold; mercury *ppts.* gold

G. E. Stahl (1660–1734), the author of the phlogistic hypothesis, extended the displacement series, particularly by studying reactions in the "wet" province. He investigated the dissolution tendency of the metals in acids (*e. g.*, nitric) and found "that above all zinc is attacked most easily by such sharp salts; after it comes iron, then copper and lead or also tin, then quicksilver, and finally silver."[28] Hence, with respect to solution rates in acids:

zinc > iron > copper > lead (>tin) > mercury > silver (> gold)

This is the calcination or oxidation (dephlogistication) order of the metals. Stahl also provided the following example with respect to the precipitation, or displacement, and strength problem. Silver is dissolved in nitric acid; then it "comes down when I throw copper in, the copper precipitates when I add iron; however, the latter deposits when I put zinc in. The zinc separates when I drip a volatile alkali (ammonia) in; the volatile alkali is separated from it when I pour in a fixed alkali (potassium hydroxide)"; there results in firm union the alkali salt of nitric acid. "However, if I pour in some vitriolic acid and drive it with fire, the stronger acid essence intervenes. . .so that the saltpeter acid is cast out." Accordingly, the precipitation (displacement) series in solutions is:[29]

zinc *ppts.* iron *ppts.* copper *ppts.* silver

The establishment of such affinity tables was so widespread in the eighteenth century, especially after St. François Geoffroy (1672–1731) set up his "Tables des différents rapports" in 1718, that derisive references were made to the "table turners." Then, in 1777, C. F. Wenzel (1740–93) brought out his "Theory of Chemical Affinity,"[30] in which, on the basis of many quantitative analyses, chemical affinity was linked with the masses of the reacting materials. He, too, gives affinity tables, namely (*a*) toward acids (or oxygen):

iron > lead > tin > copper > antimony > mercury > silver

and (*b*) toward sulfur (or arsenic):

iron > copper > tin > lead > silver > antimony > mercury

It is interesting to compare this 1777 series with that announced by Geber in the thirteenth century.

The discovery of galvanic electricity gave the ancient metals a new scientific function. Around 1804 J. W. Ritter (1776–1810), with brilliant insight, saw the connection between the "electromotive series of the metals" that had recently been announced by Volta and the centuries-old chemical affinity series: the electrical tension series runs parallel to the chemical displacement series of the metals or to their affinity for oxygen.

The historical cross section will be closed by presenting a table that can be found in all recent texts on inorganic or physical chemistry, namely the "electromotive series" of the elements in aqueous solution:

Cation	E_0, *v.*	*Cation*	E_0, *v.*
Zn^{++}	+0.76	Sb^{+3}	−0.2
Fe^{++}	+0.44	Cu^{++}	−0.34
Sn^{++}	+0.14	Hg^{++}	−0.80
Pb^{++}	+0.13	Ag^{+}	−0.81
H^{+}	0	Au^{+}	−1.5

The foregoing indicates that each metal discharges and precipitates the following metals, provided that the latter are present as cations in aqueous solution.

COMPARISON OF THEORIES

It is interesting to compare the many tabulated "affinity series" and to note their general agreement. How was it possible for the early chemists—Geber, Paracelsus, Stahl—using their erroneous and fantastic theories of mercury, sulfur, phlogiston, etc., to anticipate, for all practical purposes, the affinity series of modern electrochemistry, established quantitatively on the basis of the most recent theories? Does this seemingly amazing feat have any logical explanation?

From early times, the metals were notable because of their diverse behavior and the dualism of their opposing essential features, as well as because of their striking differences in external appearance. In addition to the solid metals, there was liquid mercury; shiny gold was in sharp contrast to dull lead, etc. The metals likewise differed greatly in their resistance to such agencies as air, water, heat, corrosive materials, etc. Geber systematized this contrast by classifying the metals as perfect and imperfect. According to this dualistic principle the metals were compound substances, originating from the same prime materials, namely from a "fixed mercury" and a "fixed sulfur." The former was the symbol of perfection, the latter symbolized corruption, *i. e.*, degradation in contrast to improvement. Accordingly, removal of this "sulphureity" ("oleity" according to Paracelsus) denoted ennoblement of the metal. The degree of perfection or imperfection depended on the quantity or proportion of the mercury and sulfur in the individual metals, and since affinity manifests itself between the different substances according to their "similar natures," the following reaction scheme followed as a matter of course:

(1) Mercury, which is related to the "perfected" metals, silver and gold, unites with metals according to the proportion of itself which they contain, in decreasing order from iron to gold (Geber, Paracelsus).

(2) The union with the "corrupting" sulfur therefore occurs in the reverse order from iron to gold, in that sulfur unites most readily with those metals which are rich in "sulphureity" (Geber, Wenzel).

(3) The action of corrosive agencies or calcination

[28] STAHL, G. E., "Ausführliche Betrachtungen," Halle, 1738, p. 261; see also pp. 218, 331.

[29] STAHL, G. E., "Zymotechnia Fundamentalis," Frankfurt and Leipzig, 1697.

[30] WENZEL, C. F., "Lehre von der chemischen Verwandtschaft," Dresden, 1777.

of metals operates on these same lines (Wenzel).[31]

(4) Zinc and iron, which have the greatest proportion of "sulphureity," dissolve most readily in acids or "sharp" materials. On the other hand, according to the phlogistic hypothesis, the dissolution (salt-formation) is related to the tendency to give up phlogiston, *i. e.*, it occurs in the order in which the metals are dephlogisticated (calcined). Phlogiston, the successor to the ancient sulfur or *terra pinguis* (J. J. Becher) manifested itself as heat and light.

(5) The displacement of metals by each other from their (salt) solutions occurs in the same order, in that the less perfect metal, in accord with its greater affinity for the acid corrupting agent, attracts the latter and thus releases (precipitates) the more perfect dissolved metal (A. Sala, G. E. Stahl).

(6) The modern electromotive series operates with the dualism of the metallic state and cation formation of the metals. Here the noble metals (*i. e.*, Geber's "perfect" metals) and the base (or "imperfect") metals appear as opposites in their behavior as cation formers, *i. e.*, as metals susceptible to "corruption" and solution. Such metals were formerly characterized by their readiness to yield up phlogiston; modern electrochemistry states that they readily yield valence electrons.

Consequently, the electromotive series is the numerical confirmation of facts and relationships uncovered by the chemical workers of the thirteenth to the eighteenth centuries on the basis of "false" theories—ideas which today are often referred to in indulgent or even derisive terms.

The lesson to be gained from this review is that the old need not always be obsolete; newer knowledge is often nothing more than the further development of ancient wisdom. Certain selected problems constitute stationary poles around which revolve the time-conditioned changes in theories.

[31] See WALDEN, P., "Mass, Zahl und Gewicht in der Chemie der Vergangenheit," Stuttgart, 1931, pp. 80–2, regarding the exact measurements of affinity by the phlogistonist C. F. Wenzel through quantitative determinations of the masses (equivalents) in displacements, calcinations, formation of sulfides, etc.

A CHEAP HOT STAGE

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AN ARTICLE appeared in a recent issue of THIS JOURNAL describing an electrically heated air-bath melting-point apparatus.[1]

This is not the first time an air bath has been used effectively for melting-point determinations.[2] It seems strange that most workers prefer the messy and sometimes even dangerous liquid baths that are almost universally indicated in laboratory directions. Many years of experience in our laboratories have clearly indicated the superiority of the air bath.

The Walter heater unit was set up as indicated in his article with the following variations. Asbestos paper was used in its assembly with the heating element consisting of two feet of No. 28 Chromel wire. A Welch power unit supplied the current.

This was mounted on a stand as in the original plan and placed about 2 cm. above the stage of a compound microscope. A piece of polaroid mounted between two glass slides was placed over the stage aperture, and three squares of asbestos paper with central holes laid over stage and polaroid served as heat insulation.

A one-inch objective was used and a piece of polaroid in the eyepiece served as an analyzer.

A small strip of tinned iron about 4 cm. long (cut from a discarded tin can), was bent so as to form a "U" trough which fitted the thermometer tube closely. A V-shaped notch was cut in one end of the trough and the prongs of the "V" were cut and bent so as to form a small platform.

Small pieces of microscope cover glass were cut with a diamond point (a carborundum crystal serves nicely). The sample to be tested was placed between two of these pieces laid on the platform prongs and attached to the thermometer so that the plates touched the thermometer bulb. When properly prepared, the tin trough functions as does the safety clip on a pencil or pen and holds the plates firmly against the bulb.

An asbestos paper shield with an observation hole cut in it and folded over the heater-tube eliminated reflections from the glass tubes. The open end of the heater-tube was closed with an asbestos shield.

Capillary tubes can be used with this apparatus; however, the field definition is not good. The fact that the source of heat is external suggests that the specimen should be inclosed in glass of approximately the same thickness as that of the thermometer bulb.

[1] WALTER, J. H., "A useful melting-point apparatus," J. CHEM. EDUC., 30, 142 (1953).

[2] KIPLINGER, C. C., AND A. YAUSSY, "Melting-point apparatus," *Science*, 93, 2407 (1941).

A PHASE-STUDY APPARATUS FOR SEMI-MICRO USE ABOVE ATMOSPHERIC PRESSURE

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THE study of phase equilibria above atmospheric pressure is complicated by the internal pressure and by special methods necessary to obtain data. The synthetic method has been used most frequently for these studies. This method entails the preparation of a solution of known composition and the visual determination of the temperature at which a phase transition occurs. The solution is sealed in a Pyrex or silica tube, and is rocked in a variable temperature furnace equipped with an observation slit. For investigations in aqueous systems up to 300°C. and 1200 p. s. i., 4-mm. silica tubing has been used for containing the solution.[1] For aqueous systems up to and above the critical temperature, 2-mm. inside diameter, 8- to 10-mm. outside diameter silica tubing has been used.[2] For both tube sizes, explosions occur frequently at the upper pressure ranges. Much time is involved in tube preparation; hence frustration is experienced from the many explosions occurring before experimental data are obtained.

An apparatus is described by which experiments of the above nature may be accomplished with relative ease and time economy on semimicro quantities of solution. In addition, investigations with this apparatus can be accomplished at much higher pressures than are possible by using apparatus for macro work. The explosions virtually are nonexistent up to and above 3200 p. s. i. The temperature of tubes containing water as a supercritical fluid has been raised as high as 600°C. without an explosion.

The general scheme of the apparatus is shown in Figure 1. The heating element consists of a cylindrical, heat-conducting block *C*, made of aluminum or graphite, 30 cm. in length and 5 cm. in diameter. A hole 8 mm. in diameter is drilled through the longitudinal axis. Pyrex sleeve *D* fits into this hole and acts as a housing for the sample tube and the thermocouple. The sample tube enters from one end and the thermocouple from the other. A window *E*, 50 mm. by 8 mm., cut through the block and normal to the sample tube hole, allows visual observation of the sample. Evenly spaced grooves *F* are machined over the block to hold the heating wire. Pyrex sleeve *B* covers the entire block. Sleeves *B* and *D* act as insulators and eliminate air currents through the slotted region. The entire heating element rests in a cradle which is not shown in the diagram.

Buzzer *A* is a small bell buzzer adapted with an alligator clamp which is attached to the vibrator. The buzzer is connected to an adjustable mount and holds the sample tube in position. Mixing of the sample is done by automatic, alternate on-off buzzing set with a Flexopulse timer.

A shield mounted between the observer and the heating element affords complete protection to the observer from tube explosions. The telescope *G* along with the light source *H*, located on the opposite side of the window, allows one to observe minute changes within the sample before they are discernible to the

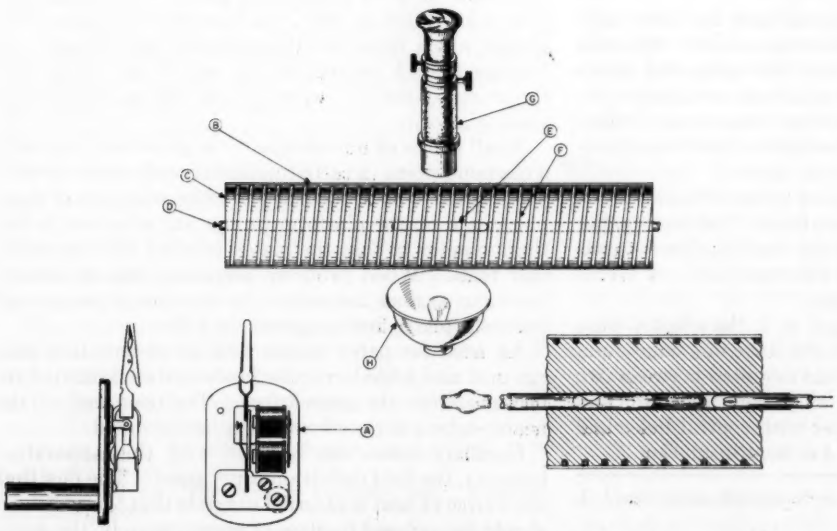

Figure 1. Component Parts of Semimicro Phase-study Apparatus

[1] MARSHALL, W. L., J. S. GILL, AND C. H. SECOY, *J. Am. Chem. Soc.*, **73**, 4991 (1951).
[2] SECOY, C. H., *ibid.*, **72**, 3343 (1950).

naked eye. Temperature control is maintained to ±1°C. with the use of a 110-volt Variac and is measured with an iron-constantan thermocouple connected to a Brown recording instrument.

Conventional 1-mm. inside diameter, 3-mm. outside diameter Pyrex tubing has been used for work in aqueous systems up to 320°C. For higher temperatures in aqueous systems silica tubing of slightly smaller bore and the same outside diameter has been used. For tube preparation a four-inch length of tubing is sealed at one end, and while this end is still hot the cool open end is inserted into an appropriate solution. The tube is removed after a suitable amount of solution is drawn into the tube, the hot end cooled, and the solution centrifuged to the sealed end. The open end is sealed at a selected distance from the solution meniscus. An additional piece of tubing is connected to the end for extension to the buzzer. After some practice, the above procedure is completed in about two minutes.

This apparatus is suitable for use in the study and exploration of all types of systems, aqueous and nonaqueous, in which high pressures are involved, in which solution components do not react appreciably with the tube, and in which the temperature is below the softening temperature of the container tube. The semimicro tubes do suffer from a disadvantage in the study of the solubility of solids which are more soluble at high temperatures than at room temperature, in that the introduction of excess solid into the tube is difficult. In common with all synthetic-tube techniques, the apparatus is not entirely satisfactory in cases where the rate of equilibration is very slow or where supersaturation is troublesome. The apparatus can be compared to apparatus using macro samples as follows:

(1) A smaller sample is used in the semimicro apparatus.

(2) Tubes can be prepared in a few minutes compared to much longer times for the macro tubes.

(3) Temperature can be changed rapidly using the semimicro apparatus. Temperature gradients are at a minimum, the variation of temperature being ±1°C. at the slit region at 300°C.

(4) Tubes can be removed and inserted at any temperature. There is little danger involved in this operation because of the small amount of solution and glass which would be scattered by an explosion.

(5) Tube explosions are practically eliminated, at least to pressures as high as 3200 p. s. i.

(6) Increased visual perception over that of the naked eye is obtained by using a telescope.

(7) The apparatus is inexpensive and could be easily constructed in college or university laboratories. It offers an easy technique suitable for demonstration or experimentation in elementary physical chemical courses. For example, the dependence of the behavior of a liquid-vapor meniscus at the critical temperature on the critical volume is easily and quickly demonstrated with a series of tubes filled with a suitable liquid to progressively increasing volume fractions. The apparatus is also very satisfactory for the demonstration of two-liquid phase regions in two-component systems.

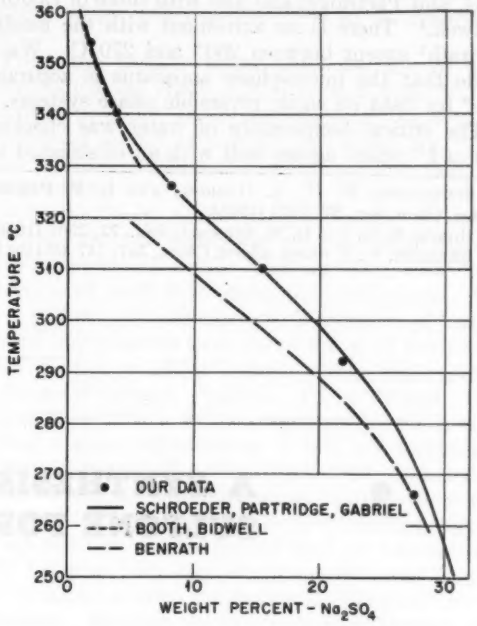

Figure 2. The System Na_2SO_4—H_2O from 250 to 355° C.

In order to establish the degree of accuracy which one might expect in using this apparatus, experimental solubility data were obtained for the system Na_2SO_4-H_2O from 250° to 350°C. and were compared with known data for this system. Solutions were prepared from Baker and Adamson c. p. Na_2SO_4 and from distilled water and were analyzed for salt by gravimetric analysis. Tubes were prepared which contained these solutions of known concentration and were run in the micro-phase apparatus.

The temperature of the furnace and, accordingly, the temperature of the solution was raised about 25° above the solubility point before crystallization occurred. The temperature was lowered rapidly to within 5° to 10° of the approximate solubility point and then lowered over a 15-minute period to the temperature at which the last solid-phase crystal disappeared. The approach to equilibrium in the apparatus was extremely rapid for this system, as evidenced by a few experiments in which the temperature was lowered 10° per minute. The solubility point was determined within one degree of the value obtained by lowering the temperature at the very much slower rate. Reliable values could not be obtained with the temperature rising because of supersaturation.

Experimental data are given in the table and are compared to some literature data in Figure 2. All experi-

mental work including rechecks of the data were completed in eight hours, thus indicating the rapid production of results. Our data agree well over most of the temperature range with the data of Schroeder, Gabriel, and Partridge[3] and also with those of Booth and Bidwell.[4] There is no agreement with the results of Benrath[5] except between 260° and 270°C. We conclude that the micro-phase apparatus is accurate to ±1° for data on easily reversible phase systems.

The critical temperature of water was checked at 374 ±1° which agrees well with an established value of 374.2°.[6] It was determined and rechecked several times within 20 minutes including the interval necessary to heat the apparatus from room temperature.

Solubility of Na_2SO_4 in Water

t°C.	*Weight per cent* Na_2SO_4
266 ± 1	27.61
292 ± 1	21.80
310 ± 1	15.40
326 ± 1	8.210
340 ± 1	3.826
354 ± 1	1.751

[3] SCHROEDER, W. C., A. GABRIEL, AND E. P. PARTRIDGE, *J. Am. Chem. Soc.*, **57**, 1539 (1935).
[4] BOOTH, H. S., AND R. M. BIDWELL, *ibid.*, **72**, 2567 (1950).
[5] BENRATH, A., *Z. anorg. allgem. Chem.*, **247**, 147–60 (1941).
[6] For compilation, see KOBE, K. A., AND R. E. LYNN, *Chem. Rev.*, **52**, 117 (1953).

A SYNTHESIS OF BIS(*p*-AMINOPHENYL) SULFONE FOR LABORATORY CLASSES

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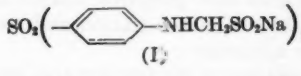
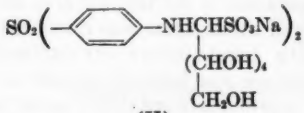
A THREE-STEP synthesis of bis(*p*-aminophenyl) sulfone[1] from *p*-chloronitrobenzene has been devised on a fairly small scale for laboratory classes in beginning organic chemistry. This compound and some of its derivatives —particularly diasone[2] (I) and promin[3] (II)—have been of interest in chemotherapy for some time.



(I)



(II)

Their use in the treatment of leprosy has been particularly successful, and they have shown some promise in tuberculosis therapy.

The first step of the synthetic series involves the displacement of a chloride ion from each of two molecules of *p*-chloronitrobenzene by a sulfide ion to form bis(*p*-nitrophenyl) sulfide. The procedure used is a modification of one already described.[4] The reaction is of particular interest since it demonstrates the ability of the *m*-directing nitro group to activate the chloride in the *p*-position for a displacement process by the selective withdrawal of part of the electronic distribution from the *o*- and *p*-positions of the ring. Another interesting and instructive feature of the reaction is that the sulfide ion also acts as a reducing agent so that some of the nitro groups are reduced and highly colored polysulfide ion is formed. A by-product, *p*-aminophenyl *p*-nitrophenyl sulfide, which is the result of such a reduction, can be isolated from the reaction mixture. The isolation of the main product is complicated by the presence of the starting material in the reaction mixture. Careful crystallization from acetic acid yields a good crop of crystals, and it is possible to isolate a fair second crop from the mother liquor.

The second step involves the oxidation of bis(*p*-nitrophenyl) sulfide to bis(*p*-nitrophenyl) sulfone. The use of sodium hypochlorite in acetic acid for the oxidation as suggested by Weijlard and Messerly[5] leads to

[1] This compound has often been designated DDS, which is an abbreviation of the name diaminodiphenyl sulfone.
[2] RAIZISS, G. W., L. W. CLEMENCE, AND M. FREIFELDER, *J. Am. Pharm. Assoc., Sci. Ed.*, **33**, 43–5 (1944).
[3] JAIN, B. C., B. H. IYER, AND P. C. GUHA, *Science and Culture*, **11**, 568 (1946).
[4] GABEL, Y. O., AND A. L. SHPANION, *Zhur. Priklad. Khim.*, **12**, 1485 (1939); *Chem. Abstracts*, **34**, 6244 (1940).
[5] WEIJLARD, J., AND J. P. MESSERLY, U. S. Patent 2,385,899, Oct. 2, 1945; *Chem. Abstracts*, **40**, 180 (1946).

virtually quantitative yields of the nitro sulfone. The preparation melts with decomposition around 262° on the Maquenne block. In fact melting points given in the literature[5, 6] vary from 225° to 290°.

The nitro sulfone is reduced without further purification by the action of stannous chloride in concentrated hydrochloric acid. This method was much faster and more clean-cut than those using iron and hydrochloric acid which have been described[6] for this reduction.

The reaction series is very useful for illustrating some of the most important chemical properties of organic compounds containing sulfur. The preparation of either sulfhydryl compounds or sulfides is usually accomplished by a displacement process on a halide involving hydrosulfide ion, sulfide ion, or a mercaptide ion. Such a reaction is demonstrated in the first step of the present series. The type of oxidation reaction peculiar to organic compounds containing sulfur in a relatively reduced form is illustrated in the oxidation of the sulfide to the sulfone. The third step demonstrates the resistance to reduction of sulfur in the oxidized form characteristic of sulfones.

Students in the beginning organic laboratory who had completed at least a semester of the course had no particular difficulty in carrying out the three-step sequence. Of the 150 students who did the experiment none failed to obtain a yield of the final product the first time through.

PROCEDURE

Bis(p-nitrophenyl) Sulfide. Set up an apparatus which consists of a 125-ml. Erlenmeyer flask fitted with a short reflux condenser. At the top of the reflux condenser fit a 60-ml. separatory funnel inserted in a cork with a groove cut along its side so that the interior of the apparatus will be open to the atmosphere. Add 12.6 g. of *p*-chloronitrobenzene (practical grade is satisfactory) and 50 ml. of isopropyl alcohol to the flask. Add a boiling chip and heat the mixture on a steam bath or a water bath. When the solution starts to boil gently, start to add 24 ml. of 2.5 *M* sodium sulfide dropwise from the separatory funnel. The total addition should take about half an hour. The mixture will turn dark because of the formation of polysulfide ion soon after the reaction is started. Boil the reaction mixture gently for two hours after the addition of the sodium sulfide is completed.

Place about 300 ml. of cold water in a 400-ml. beaker and pour in the reaction mixture with stirring. Stir until the precipitate is coagulated. Filter the solid and wash with 100 ml. of cold water. Mix the solid thoroughly with 120 ml. of 1 *N* hydrochloric acid in a 250-ml. beaker. Filter the mixture and wash the solid with 20 ml. of cold water. The filtrate should be saved for the isolation of the by-product, *p*-aminophenyl *p*-nitrophenyl sulfide.

Recrystallize the solid from 50 ml. of glacial acetic acid. Wash the product with 20 ml. of isopropyl alcohol. About 3 g. (14 per cent) of bis(*p*-nitrophenyl) sulfide, m. p. 154–6°,[7] was obtained at this point in several sample experiments. The m. p. reported[8] is 156–7°.

Treat the mother liquor with 300 ml. of water. Recrystallize the crude crop of crystals from 50 ml. of isopropyl alcohol. In several experiments the yield of this second sample of product was about 3 g. (14 per cent) with a melting point 2 to 3° lower than that of the first product.

p-Aminophenyl p-Nitrophenyl Sulfide. Neutralize the acidic solution which was obtained when the crude bis(*p*-nitrophenyl) sulfide was digested with hydrochloric acid, with 6 *N* ammonium hydroxide. Filter the yellow *p*-aminophenyl *p*-nitrophenyl sulfide. Several experiments gave about 0.8 g. (4 per cent) of product of m. p. 142–4°, which checks that reported.[9]

Bis(p-nitrophenyl) Sulfone. Fit a 125-ml. Erlenmeyer flask with a reflux condenser to which is connected a glass tube leading to but not touching the surface of some 1 *N* sodium hydroxide contained in a flask. Then any chlorine gas coming from the reaction mixture will be absorbed by the basic solution, but none of the solution can be sucked into the reaction flask. Add 1.0 g. of bis(*p*-nitrophenyl) sulfide and 30 ml. of glacial acetic acid to the flask and heat until the solid dissolves. Remove the exit tube from the top of the reflux condenser long enough to pour 20 ml. (21.1 g.) of 5.25 per cent sodium hypochlorite (commercial laundry bleach) down the condenser. Boil the reaction mixture for half an hour and then add 2 ml. of isopropyl alcohol to destroy the chlorine and the excess hypochlorous acid. Cool the solution and add 50 ml. of cold water. The product obtained by filtration is used directly in reduction to bis(*p*-aminophenyl) sulfone. A yield of 1.1 g (99 per cent) of bis(*p*-nitrophenyl) sulfone, m. p. 262° with decomposition on the Maquenne block, was obtained in several sample experiments.

Bis(p-aminophenyl) Sulfone. Add the crude bis(*p*-nitrophenyl) sulfone, either moist or dry, to a warm solution of 6 g. of stannous chloride dihydrate in 5 ml. of concentrated hydrochloric acid in a 125-ml. Erlenmeyer flask. Boil the mixture under reflux for about 15 minutes. At the end of this time all solid should be dissolved. Add 20 ml. of water, and then carefully add a solution of 8 g. of solid sodium hydroxide in 20 ml. of water. Filter the solid and wash thoroughly with water. Dissolve the product in 25 ml. of hot isopropyl alcohol, treat with decolorizing carbon, filter, and add 50 ml. of hot water to the filtrate. Cool slowly to obtain the crystals. Several experiments yielded about 0.4 g. (45 per cent) of bis(*p*-aminophenyl) sulfone, m. p. 174–6°, which checks well with that reported.[10]

[6] BURTON, H., AND W. A. DAVY, *J. Chem. Soc.*, 1946, 542; MATSUKAWA, T., B. OHTA, and T. IMADA, *J. Pharm. Soc. Japan*, **70**, 77 (1950).

[7] All melting points were corrected.

[8] See footnote 6.

[9] See footnote 4.

[10] See footnote 6.

SCIENCE AS CULTURE[1]

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Monsanto Chemical Co., St. Louis, Missouri

MODERN liberal education is a failure. It has ceased to be liberal and tends to be fossil. This statement sounds strange to scientific ears, which have long become accustomed to the eternal criticism of scientific education for its so-called lack of "liberal" studies. Like many others, I have been a member of various university advisory committees both in chemistry and chemical engineering. Invariably, these committees suggest that scientific education should include more of the humanities. Just as often, the committee is faced with complete agreement from the members of the university faculty and then is politely asked where they would insert these studies in an already overcrowded four-year program. Nevertheless, I can look back over some 25 years and see definite progress being made in this regard in practically all of our institutions of higher learning. At least we must admit that the scientific faculties are responsive to criticism and are willing to do as much as can be done to remove its cause. However, they must distinguish between those studies which are necessary and those which are, in a sense, luxuries. Since there is no absolute answer to this question, there are available for the future many hours of pleasant debate.

News item: Princeton, New Jersey, June 17, 1953. Spectators at Princeton University's 296th Commencement Exercises yesterday were amazed at the erudition displayed by the Graduating Class. In a salutatory address spoken entirely in Latin, the Seniors laughed and clapped every so often as though catching all the nuances of the classical language were second nature to them. The truth is that they all had copies of the speech with directions carefully inserted to tell them when to laugh and when to applaud.

So hath the mighty fallen. I'm not sure whether one should say "*Sic semper tyrannis*," or "*Reductio ad absurdum*." It is obvious that no man can know everything and, in spite of opinion to the contrary, about a few—such as Leonardo da Vinci—no man ever could. We conclude that education must in every age choose and select, for the man of culture, those things most important for that age. Liberal education has failed to meet this challenge by ignoring the most potent force of this modern age of ours, namely, science. In this, it has been partially abetted by scientific education which, because it was thrust out, has come to consider itself as interested only in teaching science to scientists, leaving the ordinary man of culture nowhere to go. In other words, it is my contention that, deserved as the criticism may have been of scientific education that it left out everything else, liberal education has been equally culpable in leaving out of its purview anything but the barest smattering of science.

[1] From the Presidential Address at the meeting of the Society of Chemical Industry, Nottingham, England, July 22, 1953.

CULTURE

Before we go too far, let us look for a moment at what we mean by this term "culture." The second edition of the "Oxford Dictionary" gives three definitions, as is often the habit of dictionaries. It defines "culture" as "the act of developing by education, discipline and training," as "enlightenment and refinement of tastes acquired by intellectual and aesthetic training," and as "a particular stage in civilization and the particular features of such a stage." In these definitions there is nothing that denominates the study of Latin, English literature, or chemistry, as culture, except insofar as they are particular features of a particular stage in civilization.

The Princeton anecdote would lead us to believe that valuable as it may be in itself, the study of Latin can hardly be classified as a particular feature of this particular stage of civilization in which we live. On the other hand, I imagine there are very few who will not readily admit that science is such a particular feature. This does not at all mean that there is no value in the study of Latin or Greek or any other of the amenities. Most of us who were brought up on them are quite convinced of the value of the discipline we went through. All we can say is that they are not now dominant features in our stage of civilization. We must infer, therefore, that education of the liberal-arts, or any other type that does not contain science as culture, cannot be considered as properly designed to produce the cultured man of this era.

Just as the fascinating mounds in the Near East which the archeologists uncover have been built up layer by layer by past inhabitants, so the mound of human knowledge increases layer by layer from century to century. Out of this mound each age must sort out and re-emphasize that which is most characteristic of it; so the criteria of culture differ in different ages.

When we look at the Greeks and the Romans, we see the ideal of *mens sana in corpore sano*. They were concerned very much with the body and with the mind and very little with the soul. In their culture they included literature but little of language except their own, with the addition of Greek for the Romans; much philosophy but little religion. They did include such sciences as they knew, since science had hardly yet become separated from philosophy. It was a culture of mental and physical agility.

The medieval era, on the contrary, was obsessed with

the problems of the soul. The cultured man was one of religion. Education in the things of the soul was paramount over those of the mind and body and metaphysics overshadowed physics. The great monastery schools and the universities were created primarily to save men's souls, not to teach the making of a living. Even as late as 1636 Harvard College in New England was founded for the training of ministers, lest the faith of the Puritans be lost.

With the Renaissance came the rise of the vernacular languages and literatures, putting Latin, which had been the *lingua franca* of Western Europe, into the position of a dead language. The rebirth of knowledge of pagan arts and the advent of scepticism caused a shift in emphasis to literature and the arts. This our humanists regard with nostalgic eyes, as if any one thing created by man was more human than anything else of the same origin. It must not be understood that these ages did not influence each other. The gain which the race had made in medieval times in the idea of the importance of the individual soul was not completely lost but it was transformed and became the important underlying principle of the American and French Revolutions.

Today we cannot say that philosophy or religion or even art and literature occupy the dominant positions of the age. This era is one characterized by two main streams, science and the conflict of opposing political ideologies. If we agree that the cultured man is one who has sufficient knowledge to fit his environment, we have to say that even though he may have a tremendous quantity of knowledge, if he has no comprehension of science and of political ideologies, he cannot be said to be truly cultured as of our time.

GENERALISTS AND SPECIALISTS

We would be just as far wrong the other way, if we conveyed the impression that all men should be specialized scientists or specialized political ideologists. All men were not monks in the Middle Ages, else we would not be here, but in that period, all men of any culture at all knew their religion, even when they came far from living up to it.

The problem of the generalists and the specialists is always with us. We can always expect to have men of wide interests and those of narrow. As a matter of fact, both may be cultured men, depending on the selection of their interests. The test is their consciousness and their knowledge of the chief activities of their time. Both the Latin professor, who is usually axiomatically considered a man of culture, and the engineer, who is usually not so considered, may be so intensely specialized that they fail to meet this test. By the same token, the generalist may know a great deal about many things and, therefore, be considered a man of wide culture but he may not include among those many things the ones important for this era.

Let me hasten to say that I do not mean that the specialist has no importance or that everyone should be forced into some kind of a standard pattern. I believe just the opposite, and that each of us has a right to choose his own way of life, but to be just a scientist or just a Latin professor is not enough to make one a man of culture.

The advocacy of science as culture as well as a specialty is not meant in any way to disparage the value of the various humanities. What we are saying is that science is not a thing apart but is as much one of the humanities as any other subject of human endeavor and, for the time being, it is one of the very dominant ones. Certainly we must agree that a man of culture must know something of the past, if only to understand the present and that other dominant feature of our time, the conflict of political ideologies. It is well to know literature and the arts. A man can know something about painting and books without being a painter or a writer, and so he can know something about science and not be a scientist.

It all comes down to values, to judgment of what it takes to best pursue happiness, by which I mean the greatest possible development of activity for the good. For some, this ideal calls for specialization and these must and should follow it. For most, it calls for the greatest knowledge and understanding of the problems and activities of their time. The culture of today is vastly conditioned and influenced by science, and the modern man ignorant of science can no longer be considered a man of culture.

DIVISION OF CHEMICAL EDUCATION

OF THE AMERICAN CHEMICAL SOCIETY

Treasurer's Report, September 1, 1953

THE membership as of September 1 totals 1038, 988 members in good standing and 50 who have not paid 1953 dues.

Our balance on hand in the Division account has increased $470 in the last year. Of this amount perhaps $200 is represented by additional dues paid in advance and the remainder by the fact that for the year ending September 1, 1952, we spent $622 on committee activities and in the year just past but $288.

DIVISION ACCOUNT

Receipts:			
Balance on hand 9/1/52		$1279.74	
Dues		17.00	
Received from F. D. Martin 11/1/52 ($996.74 plus a $300 bond deposited with R. V. Mellefont)		1296.74	
Interest on bonds (includes $87.50 transferred to JOURNAL Account; see below)		95.00	
Dues previous to 1953		36.00	
Dues for 1953		856.00	
Dues paid in advance		339.00	
Total receipts			$2622.74
Expenditures:			
A. C. S.—Dues receipt cards	$ 27.50		
A. C. S.—Separates Atlantic City	47.09		
A. C. S.—Separates Los Angeles	55.66		
		130.25	
Secretary's office		178.17	
Treasurer's office			
Postage	27.00		
Help in mailing and revising mailing list	33.05		
Supplies	24.19		
Addresserette and accessories	102.87		
Bank charges	2.52		
		189.63	
Committees			
L. L. Quill, A. A. A. S. Coop. Com.	88.18		
O. M. Smith, Teaching College Chem.	200.00		
		288.18	
Interest transferred to JOURNAL account		87.50	
			873.73
Net balance on hand 9/1/53			1749.01
Assets distributed as follows:			
Checking account—"Division of Chemical Education, F. B. Dutton, Treasurer"—East Lansing State Bank, East Lansing, Michigan			1449.01
Three (3) U. S. Savings Bonds, Series G, at $100 ea., Nos. C 825778/80 G. Deposited with R. V. Mellefont, Treasurer, American Chemical Society, 1155 16th Street, N. W., Washington 6, D. C.			300.00
Total			$1749.01

JOURNAL ACCOUNT

Balance on hand 9/1/52		
Bonds	$18,000.00	
Cash	1,488.17	
		$19,488.17
Receipts:		
Chemical Education Publishing Co., Easton, Pennsylvania. Net transfer to JOURNAL fund from 1952 profits	2,487.01	
Interest on bank account	56.34	
Interest on bonds	450.00	
Total receipts		2,993.35
Expenditures:		
None		
Balance on hand 9/1/53		$22,481.52
Assets distributed as follows:		
Savings account No. 02006, East Lansing Savings and Loan Association, 303 Abbott Road, East Lansing, Michigan		4,481.52
Seven (7) U. S. Savings Bonds, Series G, $1000 ea., Nos. M.: 5560890G, 5560861G, 5560855G, 5560856G, 5560857G, 5560358G, 5560859G, deposited with R. V. Mellefont, Treasurer, American Chemical Society, 1155 16th Street, N. W., Washington 6, D. C.		7,000.00
Four (4) U. S. Savings Bonds, Series G, $1000 ea., Nos. M: 5866176G, 5855177G, 5855178G, 5855081G (deposited with R. V. Mellefont as above)		4,000.00
Four (4) U. S. Savings Bonds, Series G, $1000 ea., Nos. M: 7280064G, 7280066G, 7280067G, 7279936G (deposited with R. V. Mellefont as above)		4,000.00
Three (3) U. S. Savings Bonds, Series G, $1000 ea., Nos. M: 7438009G, 7438010G, 7437661G (deposited with R. V. Mellefont as above)		3,000.00
Total		$22,481.52

F. B. DUTTON, *Treasurer*

Report of Committee on Codes for Employment of Graduate Assistants

SINCE the adherence to any "code" in the employment of graduate assistants must be on a distinctly voluntary basis, the committee felt that its function must be first of all to try to ascertain the sentiment of faculties of the various institutions over the country. On the basis of preliminary discussions by the committee, three possible statements differing in the specificity of their provisions were drawn up. A questionnaire on these was then sent to chemistry departments of the various schools and colleges on the "approved" list of the Society (A. C. S. Committee on Professional Training, Progress Report No. 23, *Chem. Eng. News*, 29, 396 (1951)).

The institutions answering are a representative list both of larger and smaller schools. A wide variety of opinions was expressed, of course, but in general the results were favorable to the establishment of a code and seem to indicate that a trial would be practicable.

Four replies expressed the view that such codes are simply not practical, four could be classed as doubtful of the results, and ten preferred not to be bothered, considering that the trouble involved would outweigh any good accomplished. Thus a bit less than 16 per cent of the answers were unfavorable. The majority, some 84 per cent of the answers, were favorable to a code. Since a number of those objecting to the codes were also willing to cooperate if other schools desired it, a total of 97 per cent of the answers expressed willingness to try a code.

No outstanding preference was evidenced for any one of the three codes over the other two, but Code II seemed to be somewhat preferred over the others. It received a positive rating in the largest number of cases; it was listed first most frequently and third least frequently.

The basis expressed for objection to a code was almost uniformly the feeling that not all schools would actually cooperate, and those who did follow the code would be at a disadvantage. On the other hand, a number of institutions are now following essentially the suggested practice and feel that it has been best in the long run, although it may have lost an occasional graduate for them.

If a trial is to be made, emphasis should be given to the fact that the code is simply proposed as a basis for voluntary cooperation in a reasonably flexible plan. Some chemistry departments may not be able to participate for legal or administrative reasons. Others may, of course, simply not agree that the suggested procedures are best. However, even though not every institution may follow such a code it seems that a large majority will do so. Many opportunities for misunderstandings between departments can be eliminated; and much can be gained by stating and exemplifying clearly for students general principles of good practice.

QUESTIONNAIRE

Accompanying the questionnaire below, the following covering letter was sent to all institutions on the Accredited List:

"Recently a special committee of the Division of Chemical Education of the American Chemical Society was appointed to study the question of a proposed code to be followed in handling appointments of teaching assistants—the objective being to establish some simple procedure which might help in avoiding embarrassment or difficulties for graduate students and misunderstandings between departments. The committee feels that, since such a code must be on a purely cooperative basis, our first objective should simply be to ascertain the wishes and interests of the various departments of chemistry over the nation.

"For your consideration we have listed, therefore, three alternative statements of a possible code and have noted several questions on which we particularly need information. We would greatly appreciate your answering these questions, and would also be glad to have any comments or suggestions you might wish to make on the proposals."

Code I

Code for Universities

(1) Offers of teaching assistantships for the following September shall not be made before March first.
(2) Recipients shall have two weeks to accept or reject an offer.
(3) Offers of assistantships will not knowingly be made to students who have already accepted a similar appointment at another institution.

Code for Students

(1) Students shall not resign one teaching *assistantship* to accept another.
(2) Students may resign a teaching *assistantship* to accept a *fellowship* at any time prior to June first.
(3) Students who decide to resign an *assistantship* for any reason shall give notice of such decision at the earliest possible date.
(4) Students who accept an *assistantship* shall give notice of such action immediately to all other schools where applications have been submitted.

Code II

Offers of assistantships for the following September will, in general, be made on or just after March first. Recipients will be asked to accept or reject the offer within two weeks.

Thereafter, an offer of an assistantship will not knowingly be made to a student who has already accepted a similar appointment at another institution.

Should an offer of an assistantship be made before March first, it should be stated that definite acceptance or rejection of the offer is not necessary until March 15.

Students who accept assistantships should give notice to all other schools to which applications were submitted.

A student who decides to resign an assistantship for any reason should give notice of this decision at the earliest possible date. A student should not simply resign one teaching assistantship to accept another, but he may always request release from a previous commitment if a better opportunity arises. He may resign a teaching assistantship to accept a fellowship at any time prior to June first. After that date, replacement becomes a critical problem; so he should always make certain release from one position is possible before accepting any other.

Code III

To avoid misunderstandings between schools, or embarrassment to prospective graduate students, it is agreed that—regardless of the exact date of receipt of an offer—March 15 shall be designated as the final date for a student to accept or reject an offer of a teaching assistantship for the following September. Thereafter, no school will knowingly offer an assistantship to a student who has already accepted a similar position elsewhere.

Questions on Proposed Codes

Would your department be able and willing to cooperate in following one of the above codes of procedure in hiring teaching assistants, if approved by other departments?

Would you prefer not to bother with such a code at all?

Please indicate your first, second, and third choices from the three alternative statements of a code.

LIST OF INSTITUTIONS ANSWERING

School	*Location*
Agricultural and Mechanical College of Texas	College Station, Texas
Alabama Polytechnic Institute	Auburn, Ala.
Antioch College	Yellow Springs, Ohio

Beloit College	Beloit, Wis.
Boston College	Chestnut Hill, Mass.
Boston University	Boston, Mass.
Bowling Green State University	Bowling Green, Ohio
Bradley University	Peoria, Ill.
Brigham Young University	Provo, Utah
Bryn Mawr College	Bryn Mawr, Pa.
Bucknell University	Lewisburg, Pa.
Case Institute of Technology	Cleveland, Ohio
Catholic University of America	Washington, D. C.
City College of New York	New York, N. Y.
Clarkson College of Technology	Potsdam, N. Y.
Colgate University	Hamilton, N. Y.
College of Wooster	Wooster, Ohio
Cornell University	Ithaca, N. Y.
Dartmouth College	Hanover, N. H.
Davidson College	Davidson, N. C.
DePauw University	Greencastle, Ind.
Drexel Institute of Technology	Philadelphia, Pa.
Duke University	Durham, N. C.
Emory University	Emory University, Ga.
Fordham University	New York, N. Y.
Gettysburg College	Gettysburg, Pa.
Harvard University	Cambridge, Mass.
Haverford College	Haverford, Pa.
Illinois Institute of Technology	Chicago, Ill.
Indiana University	Bloomington, Ind.
Iowa State College	Ames, Iowa
Johns Hopkins University	Baltimore, Md.
Juniata College	Huntingdon, Pa.
Lawrence College	Appleton, Wis.
Lehigh University	Bethlehem, Pa.
Louisiana State University	University, La.
Massachusetts Institute of Technology	Cambridge, Mass.
Miami University	Oxford, Ohio
Michigan State College	East Lansing, Mich.
Mississippi State College	State College, Miss.
Monmouth College	Monmouth, Ill.
Montana State College	Bozeman, Mont.
Mount Holyoke College	South Hadley, Mass.
New York University	New York, N. Y.
N. Carolina University	Raleigh, N. C.
Northeastern University	Boston, Mass.
Northwestern University	Evanston, Ill.
Occidental College	Los Angeles, Calif.
Ohio State University	Columbus, Ohio
Ohio Wesleyan University	Delaware, Ohio
Oklahoma A. and M. College	Stillwater, Okla.
Oregon State College	Corvallis, Ore.
Pennsylvania State College	State College, Pa.
Pomona College	Claremont, Calif.
Princeton University	Princeton, N. J.
Purdue University	Lafayette, Ind.
Queens College	Flushing, N. Y.
Reed College	Portland, Ore.
Rensselaer Polytechnic Institute	Troy, N. Y.
Rutgers University	New Brunswick, N. J.
St. Louis University	St. Louis, Mo.
St. Olaf College	Northfield, Minn.
Smith College	Northampton, Mass.
South Dakota A. and M.	Brookings, S. D.
State College of Washington	Pullman, Wash.
State University of Iowa	Iowa City, Iowa
Syracuse University	Syracuse, N. Y.
Temple University	Philadelphia, Pa.
Trinity College	Hartford, Conn.
Tufts College	Medford, Mass.
Tulane University	New Orleans, La.
Union College	Schenectady, N. Y.
University of:	
Alabama	University, Ala.
Arizona	Tucson, Ariz.
Arkansas	Fayetteville, Ark.
Buffalo	Buffalo, N. Y.
California	Los Angeles, Calif.
Chicago	Chicago, Ill.
Colorado	Boulder, Colo.
Connecticut	Storrs, Conn.
Delaware	Newark, Del.
Denver	Denver, Colo.
Detroit	Detroit, Mich.
Georgia	Athens, Ga.
Idaho	Moscow, Idaho
Illinois	Urbana, Ill.
Kansas	Lawrence, Kan.
Louisville	Louisville, Ken.
Maine	Orono, Me.
Maryland	College Park, Md.
Massachusetts	Amherst, Mass.
Michigan	Ann Arbor, Mich.
Minnesota	Minneapolis, Minn.
Missouri	Columbia, Mo.
Nevada	Reno, Nev.
New Hampshire	Durham, N. H.
North Carolina	Chapel Hill, N. C.
North Dakota	Grand Forks, N. D.
Notre Dame	Notre Dame, Ind.
Oklahoma	Norman, Okla.
Oregon	Eugene, Ore.
Portland	Portland, Ore.
Southern California	Los Angeles, Calif.
Tennessee	Knoxville, Tenn.
Texas	Austin, Texas
Virginia	Charlottesville, Va.
Wisconsin	Madison, Wis.
Utah State Agricultural College	Logan, Utah
Vanderbilt University	Nashville, Tenn.
Vassar College	Poughkeepsie, N. Y.
Virginia Polytechnic Institute	Blacksburg, Va.
Wabash College	Crawfordsville, Ind.
Washington University	St. Louis, Mo.
Wayne University	Detroit, Mich.
Wellesley College	Wellesley, Mass.
West Virginia University	Morgantown, W. Va.
Western Reserve University	Cleveland, Ohio

SUMMARY OF ANSWERS

No. sent out: 189
No. replies: 118

Part I

Distribution of answers:

				Preference	
Codes not practical	4				
Prefer to have no code	10	Code	I:	2nd	2
				3rd	4
			II:	1st	4
				2nd	3
			III:	1st	4
				2nd	1
				3rd	1
Doubtful	4		I:	2nd	1
			II:	1st	2
			III:	1st	2
				3rd	1
Don't employ assistants but favorable to codes	9		I:	2nd	5
				3rd	1
			II:	1st	6
				2nd	1
				3rd	1
			III:	1st	2
				3rd	4
Generally favorable	91		I:	1st	28
				2nd	29
				3rd	15

		II:	1st	41
			2nd	19
			3rd	8
		III:	1st	23
			2nd	12
			3rd	32
Total.....	118	Code I:	1st	28
			2nd	37
			3rd	20
				—
				85
		II:	1st	53
			2nd	23
			3rd	9
				—
				85
		III:	1st	31
			2nd	13
			3rd	38
				—
				82

Part II

Samples from letters of appointment now in use:

(1) We would appreciate having your acceptance as soon as possible, but it should be understood that you have until April 15th to withdraw your acceptance if it would be in your best interest to change your plans.

(2) You are advised that in accordance with current recommendations of the Association of American Universities, you are to feel free to rescind your acceptance at any time through April 15, 195–, without prejudice, for the purpose of accepting any other fellowship, scholarship, or assistantship. In return, we hope you will keep us informed as to your plans so that we may take appropriate steps to keep filled our quota of assistantships.

(3) You may accept this appointment at any time with the understanding that you may withdraw the acceptance prior to April 15, 195–, without prejudice. It is possible that you may prefer to accept a similar offer from some other institution which you have received. Your official appointment will not be made until after July 1, 195–, but your acceptance of this offer will be equivalent to appointment.

Part III

A few direct quotations from individual letters embodying criticisms or specific suggestions:

(1) These codes don't work in the long run—there is always someone who breaks them whenever it suits his convenience to get a good man—I think they are unrealistic as it makes those people who abide by them left with the poorer men.

(2) I cannot get very enthusiastic about codes, especially when there is no machinery for their enforcement, and I certainly cannot support the setting-up of machinery for enforcement. We hear a lot about "our free-enterprise system" (which probably never has existed to the extent many people believe), but if we begin to surround our appointments by restrictive codes, we are doing away with much of our free choice. Gentlemanly behavior should prevail in these relationships. . . . Those departing from such practices will not be cured by edict. I'll have to vote a tepid "no" on this proposal.

(3) In general the feeling of the members was very sympathetic toward the efforts your committee is making. One of the difficulties was that all three codes seem to prevent a university and a graduate student from making a definite commitment even though both were quite willing to make such a commitment. In our own case we usually have six or eight teaching assistantships and if several of our offers were turned down on March 15th, we feel that we would be at quite a disadvantage then in trying to fill the positions. We all realize what a difficult job it is to put in any rules and it almost seems to me that some sort of clearing house is necessary if there is going to be cooperation.

(4) Assistantships become effective at other dates than September. They are outside the code and confuse the whole plan.

(5) I should like to see paragraphs 1 and 2 combined and made to read, "Students shall not resign one teaching assistantship or fellowship to accept another after April 15th and shall not be accepted by a second institution until a written release from the first institution is submitted."

(6) In these days in which there is much sponsored research in which the various agencies of the government are quite active I think that June 1st as a deadline beyond which an assistantship would not be resigned in order to accept a fellowship would often entail some hardship because many of the government research programs are set up about July 1st and this seems to me to be a more appropriate date. It is true that this proposes a less favorable condition for the department seeking teaching assistants but the situation seems to me to demand a change.

(7) It certainly would not be ethical for a university to withdraw an offer of an assistantship which had been accepted by a student, even if a more likely candidate appeared later. It seemed to us similarly unethical for a student to resign an assistantship which he had accepted and to go to another university to accept either a more advantageous assistantship or a fellowship.

In drawing up such a code, you would also have to be very careful to define what is meant by an assistantship, since many universities classify as "teaching fellows" those who would be called "assistants" if they did the same type of work elsewhere. Is this code intended to cover only teaching assistants, or to include also people carrying out research work on grants of various types, sometimes classified as "research assistants" and sometimes as "research fellows"? These are points which your committee certainly will have to clarify before you can get widespread agreement and acceptance of any code.

(8) Much duplicaton of effort both on the part of the applicant and of the institution offering the assistantship, etc., can be avoided if it is possible for the applicant to send out one application to the institution to which he would prefer to go or to which he is referred on the advice of his major professor and expect and receive in a reasonable time an acceptance or rejection. This might be effected very early in the year preceding the appointment. Then the applicant could settle down to work if accepted or make application elsewhere.

(9) I can see no reason in the world why a student should be given an opportunity to resign from an assistantship in order to take a fellowship. This is a very unethical thing to do. I can think of nothing that will work more against the entire assistantship system both because it will make hiring such people extremely doubtful and it will materially reduce the quality of graduate assistants anyway. Our practice is to put all new men on as assistants and to promote to fellows in following years. In this way they have the advantage of the assistantship experience and they are not forced to take a problem which they might not want under a professor whom they might not have chosen under some fellowship arrangement. The great number of sponsored fellowships now available is a most dangerous thing to pure research and it might well destroy the freedom of choice of our graduate students which is the basis of our free research system.

(10) It appears to be unrealistic to have any code for students, since many of them will never hear of it, and their actions are largely determined by the policies of the chemistry departments offering them assistantships.

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Report of the

NEW ENGLAND ASSOCIATION OF CHEMISTRY TEACHERS

EVALUATION OF LABORATORY WORK IN CHEMISTRY[1]

CARL P. SWINNERTON
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IT MAY be well to start our discussion of the evaluation of laboratory work by taking a very general view. Particularly is this desirable in discussing laboratory work at the secondary school level. For, while the importance of the laboratory is taken for granted in the college and the university, we can no longer feel assured that it has such importance in many school systems.

There are several reasons for this weakening of the traditional prestige of the laboratory. Some are administrative. The laboratory period should really be longer than the usual school period. Ordinarily this means a double period, and the person who makes out the school schedules immediately begins to tear his hair. It is unquestionably awkward to fit double periods into the ordinary schedule, especially in the smaller schools where there is the usual diversity of pupil demands for courses, but where the number of available teachers is limited. It makes less trouble in the larger schools, but still enough—in some quarters—to cause a constant pressure from above toward the limitation of the laboratory work to single periods. This is especially true since so many administrators have had so little experience in science and in the teaching of science. The loss to the pupils which results from such a change weighs less with the administrator than the freedom from headaches that he gains.

The fact that in many states there is no suitable body for setting and enforcing standards in this respect has been truly unfortunate. It is possibly time for us as an Association to consider taking an active lead in such matters.

The cause of the administrator was aided and that of the teacher was weakened by some widely publicized studies of students who were taught science in the usual way, including laboratory work, in comparison with others who had no laboratory work but watched demonstrations instead. The progress of the latter group, as checked by tests, was reported to be substantially that of the former, and a move was under way for abolishing all laboratory work by individual pupils.

It is not questioned that a skilled experimenter can present a demonstration more quickly and in a sense to better advantage than an unskilled student. Much more ground can be covered in this way and those of us who have to prepare candidates for the College Entrance Examination Board test in March are sorely tempted to use laboratory time for teaching and demonstration. A youngster taught by such methods will, in the course of the year, receive a much broader basis of factual information and may be expected to do correspondingly well *in an objective test on such information.*

Why, then, should there be laboratory work in chemistry? Just what is its purpose? There have been a number of answers. Many texts give long lists of them: to teach the scientific method; to train in accurate observation and in the drawing of sound conclusions, etc. But very rarely has it been stated explicitly that the purpose of laboratory work is *to teach chemistry*, and to teach chemistry *better* than can be done by other methods.

This means not merely instruction in the special techniques of chemistry—in filtering, in glass bending, in pouring liquids, or in collecting gases. Through laboratory work the boy or girl gains a comprehension of materials by manipulation and by first hand observation of substances, their reactions, and the basic principles that govern their behavior.

It is still true that a person learns by doing. In a laboratory course he may deal with fewer facts, but he becomes acquainted with them more intimately, and he gets a practical knowledge of the properties of matter that are not covered in the ordinary objective test. He learns that hot glass stays hot, and may not be cooled by holding it under the tap; that gas will not leave a generator through the delivery tube if the thistle tube does not dip beneath the sealing liquid; that a test tube is not logically clamped at the spot where it is to be heated, and so on. All these things may pass un-

[1]Presented as part of a symposium at the 14th Summer Conference of the New England Association of Chemistry Teachers, University of Vermont, Burlington, Vermont, August 22, 1952.

noticed if he is merely watching a good experimenter.

He may not cover so much ground, but if the experiments have been well chosen to emphasize key facts, procedures, and relations, he will inevitably know them better than if he has only seen someone else do them. My own experience with both kinds of teaching has convinced me that a well-thought-out and functional laboratory course teaches chemistry more thoroughly than any other method. And there is a genuine need for a number of us to come right out and say so.

Again, this Association, through its Committee on Education, might well draw up a list of fundamental experiments, to match its syllabus on the minimum content of a chemistry course. For there are doubtless as many ancient, outmoded, non-functional, or merely cookbook laboratory manuals now in use as there are obsolete texts or obsolescent teachers. While we are about it we might also state what, to us, seems to be the proper length for laboratory periods and the proper number of such periods in the week and in the year. We will be doing the chemistry teachers of New England a service in thus committing ourselves.

As for the evaluation of the laboratory work done by students, there is not so much to say at this time. A statistical study in secondary schools—such as Dr. Currier has made in colleges[2]—would be worth while, but there has not been time for me to make one. Perhaps with a little audience participation we can take a reasonable sampling here. I will ask the following questions and record your responses.

Questionnaire

(Total number of secondary school teachers polled..... 38)

(1) How many of you have laboratory work for individual students in chemistry in your schools?..... 38

(2) How many have laboratory work but do not count it in making up the grades?..... 2

(3) How many count laboratory grades as a fixed percentage of the total grade in chemistry?..... 14

(4) How large a percentage:
- less than one-third..... 4
- approximately one-third..... 9
- more than one-third..... 1

(5) How many count laboratory grades but not in a fixed percentage..... 25

(6) On what basis is the laboratory grade made up:
- on the average of grades of experiments done..... 8
- on quizzes on laboratory work..... 2
- on some combination of graded experiments and quizzes..... 21

For my own part, I am swinging rapidly away from the actual grading of laboratory reports, except early in the year when the student is learning the form of such reports and the distinction between observations and conclusions. But since the purpose of the laboratory period is to teach chemistry I train my pupils to expect a brief quiz the next time they come to class after doing an experiment. The quiz is usually limited to materials covered by the experiment and is counted, along with other quizzes, as part of the grade for the week.

With small groups this works quite well. It does not involve the correction of large numbers of papers, and it places the emphasis where the emphasis properly belongs—on testing the knowledge of chemistry gained in the laboratory. Those of you who have large classes must probably adopt a different procedure. It will be interesting to hear just what you do.

In closing, though, let us not forget that laboratory work in secondary schools is too frequently on the defensive. It will remain so until it is more highly evaluated by superintendents, by principals, and by us as teachers of chemistry.

[2] CURRIER, A. J., "Evaluation of laboratory work in general chemistry," J. CHEM. EDUC., **30**, 207 (1953).

BOOKS FOR HIGH-SCHOOL STUDENTS

IF YOU have read a book or an article which you think the enterprising student of elementary college chemistry or high school chemistry would profit by reading, you might pass the information along.

A master's thesis is being undertaken by Mr. James Halm under the direction of Dr. Theodore A. Ashford at St. Louis University. The object is to compile a bibliography which would be useful to teachers of elementary chemistry and may serve as a guide in enriching the chemistry library. Send the title of the book or article, together with a characterization in a few sentences, to Dr. Ashford. This need not be restricted to recent publications.

To the Editor:

The article on "Glass in the biblical literature" in the JOURNAL OF CHEMICAL EDUCATION, **30,** 415 (1953), undertakes a study in the history of technology and culture which would be of some interest if it were sound. Unfortunately the authors seem to have collected most of their instances by using a concordance to the 1611 translation, with the result that the majority of their examples have nothing whatever to do with glass.

In many cases the original Hebrew or Greek word means simply "mirror." This is the case with regard to Job 37:18 (erroneously given as Job 7:18), I Corinthians 13:12, James 1:23, and Ecclesiasticus 12:11. Isaiah 3:23 may be another case but here there is a question of the meaning of the Hebrew word. Many recent translators supported by the context, the ancient Greek version, and similar words in cognate languages, render it "garments of gauze" or something of the kind, instead of "mirror."

Of course mirrors are now commonly made of glass, but students of biblical antiquities are unanimous in the opinion that such mirrors were not known in the culture in which the biblical literature originated. This may be quickly confirmed by a look at any Bible dictionary, or from the "Jewish Encyclopedia," which states (*s. v.* "mirror"), "In ancient times mirrors were invariably made of metal." The quotation from the "Jewish Encyclopedia" which the authors do make indicates explicitly that it is referring to talmudic times, a period several hundred years later than the latest biblical writings, with quite a different cultural background. It therefore affords no presumption that the mirrors mentioned in the Bible were glass.

Three other passages cited by the authors need comment. Psalm 56:81 refers to a bottle for tears which might possibly be of glass, but this is far from likely. On the one hand, the Hebrew word here is one which in all other cases means a skin "bottle," while on the other hand the small glass flasks which are sometimes supposed to be "tear bottles" were not dug up with labels on them and are more probably flasks for perfume. Furthermore, there is no evidence that such bottles, even if rightly identified as used for tears, were known to or used by the Hebrews. Again, despite the authors' assurance that the bottle in Psalm 119:83 is "evidently" a glass bottle, nothing of the kind is evident and the word is here rendered "wineskins" by more than half a dozen recent translators, including Dr. Solomon B. Freehof (to whom the authors acknowledge some indebtedness), in his "The Book of Psalms," Cincinnati, 1938, p. 347. Another passage is II Corinthians 3:18, where there is no noun for "mirror" in the original but only a verb which may be translated simply "reflect."

To sum up, the only certain reference to glass in the Old Testament is Job 28:17 where wisdom is said to be as rare as glass. The only references to glass in the New Testament are those in Revelation. Here they occur in descriptions of scenes in heaven, so that in New Testament as well as Old the few real references point to the rarity of glass rather than to its "significant role" "in the scheme of living." The references given to the Talmud suggest the same point of view.

Studies such as this article which cut across our rigid divisions of the various fields of learning are to be welcomed, but those who undertake them should realize that they need to be really at home on both sides of the fence.

FREDERIC R. CROWNFIELD
GUILFORD COLLEGE
GUILFORD COLLEGE, NORTH CAROLINA

To the Editor:

It is good of Mr. Crownfield to call attention to the fact that some recent scholars deny that many of the references usually translated as "glass" actually mean glass. It may well be that the scholarship of the next generation will change in this regard to earlier interpretations. Biblical scholarship, based as it is on continuing discoveries in language and archeology, changes considerably from time to time.

Perhaps the only sure way to come to a conclusion as to whether glass was in fairly wide use in biblical times is on general cultural lines. There is no doubt that Bible lands were for many centuries under the control of Egypt and there can be no question that glass-culture was well developed in Egypt as early as the fourth millenium B.C. See Joseph Jacobs' article in the "Jewish Encyclopedia" on glass, Vol. V, p. 677. If there is anything that modern archeology is proving all the more strongly, it is the deep and persistent influence of Egyptian civilization over the Bible lands. If, then, the Egyptians had glass for millenia, there is an overwhelming presumption that the inhabitants of Palestine did, however much varying biblical scholarship may change its mind about certain individual verses.

ELROSE R. SILVERMAN
ALEXANDER SILVERMAN
UNIVERSITY OF PITTSBURGH
PITTSBURGH, PENNSYLVANIA

To the Editor:

"What did you do in lab today?" I once asked of a student taking an elementary chemistry course. "We proved the law of conservation of mass," he said, leaving me wondering whether to try myself, or to leave to his

instructor, the task of explaining that no one has ever proved this law, and that we know it only from our persistent failure to find an exception to it.

This is an illustration of the vast gap that often lies between getting students to do an experiment, and getting them to understand the experiment they have done. It is quoted by way of preface to voicing a certain dismay at the article "Determining Avogadro's number," THIS JOURNAL, September, 1953, page 460. For the experiment there described assuredly does *not* determine that famous number.

The experiment described is simple. A current, measured in ampere-seconds (coulombs), is made to electrolyze water (with the usual 10 per cent H_2SO_4 added "to increase the conductivity"), and the volume of hydrogen and of oxygen produced is measured, all appropriate corrections being applied. By the use of the familiar constant 22.4 liters, the number of coulombs required to liberate one gram molecular weight is easily calculated. The students are then "given" the charge on one electron, and then, provided they understand the units involved, they can calculate the number of molecules in a gram molecular weight—6.06×10^{23} in a numerical example given, very close to the accepted value, 6.02×10^{23}.

As for the magnitude of the electronic charge, it is interesting to note that this paper refers back to THIS JOURNAL, 1952, page 94, for "an experiment in which the very small number representing the charge on the electron has been successfully determined by students in elementary chemistry." The experiment quoted there is even simpler. A current measured in coulombs is allowed to plate out copper, which is weighed. This is, of course, a well-known experiment due to Faraday, although neither he nor anyone else in the nineteenth century was able to calculate the electronic charge from it. But for the students this is very easy—they are "given" Avogadro's number!

Neither of these experiments leads to a knowledge of either Avogadro's number or the electronic charge. *One* experiment, which may be Millikan's oil drop experiment, or Perrin's on the Brownian movement of gamboge particles, or one of several other types, leads to *both* constants. They come into our knowledge together: we can determine the electronic charge by purely electrical means, and then by using Faraday's laws, which depend upon much simpler techniques, we can easily calculate Avogadro's number. But we cannot go beyond Faraday by using Faradayan techniques alone.

By way of anticlimax, or perhaps by way of splitting hairs, it may be noted that one other constant has to be "given" to the students—the magic figure, 22.4 liters. I am prepared to assume that the students have determined by some sort of experiment (or partly by lecture demonstration) that the molecular weight of hydrogen is 2. But have they determined the volume of 2 grams of hydrogen? They would only have to evacuate and weigh a glass vessel of measured capacity, and then fill it full of hydrogen (at a measured pressure) and weigh again. Sounds simple, doesn't it? It is indeed so simple in conception, and therefore can be explained so easily, that it can well be left out of the experimental program, since in practice it demands most bothersome precautions of a kind that have no pedagogical value for an elementary chemistry course. On the other hand, the measurement of the volume of oxygen and hydrogen electrochemically released by a known amount of current requires the most interesting corrections; the temperature and pressure must be read, and hydrostatic head and water vapor pressure must be allowed for, remembering in both cases that we are dealing with 10 per cent sulfuric acid, not water. This is excellent for elementary chemistry students, and it gives a splendid opportunity, as the authors of the paper say, "for bringing together and applying several laws and principles studied earlier."

ANTHONY STANDEN
THE INTERSCIENCE ENCYCLOPEDIA, INC.
BROOKLYN, NEW YORK

To the Editor:

The paper by Gillis[1] on the evaluation of molecular formulas is an interesting application of topology to chemistry. His method is equivalent (assuming normal valences) to the general equation

$$2(U + R) = 2 + \sum (v - 2)$$

where U is the number of multiple bonds, R the number of rings, v the valence of an atom, and where the summation is carried out over all the atoms of a discrete molecular species, *i. e.*, one in which all the atoms are linked by directed bonds. This equation was derived by the writer and his colleagues mainly for checking molecular formulas and cipher notations. Neglecting bond multiplicities, the equation becomes the Check Rule of the Gordon-Kendall-Davison cipher notation[2] and in the form of a continuous summation has been applied to the fully automatic error-detecting, error-correcting, and group-sorting programs proposed for a special-purpose computor-sorter.[3] Although these relationships are readily derived inductively, it is interesting to realize that they are generalizations of a theorem in plane geometry by Cauchy.[4]

The concept of an equivalent hydrocarbon, introduced by Gillis, and his derivation of the number of rings and multiple bonds from the equivalent *saturated* hydrocarbon, are both more readily memorized and more convenient than our more formal equation. How-

[1] GILLIS, R. G., J. CHEM. EDUC., **30**, 126 (1953).

[2] GORDON, M., C. E. KENDALL, AND W. H. T. DAVISON, *Proc. Intern. Congr. Pure Appl. Chem., 11th Congr., London*, 1947, Vol. II, Sec. III., p. 115; "Chemical Ciphering," Royal Institute of Chemistry, London, 1948.

[3] DAVISON, W. H. T., AND M. GORDON, "A punched-card method of sorting GKD ciphers for any chemical group," paper read to A. C. S. Jubilee Meeting, 1951 and in press (*Advances in Chem. Ser.*).

[4] CAUCHY, "Oeuvres Complètes," Gauthier-Villars, Paris, 1905, Vol. XIII, p. 15.

ever, the difficulty which arises when applying his Rule 2 to the salts of polyfunctional acids is due to the fact that the equation given only applies to a discrete molecular fragment; one must know the number of such fragments to calculate the number of rings and multiple bonds. An alternative form of Rule 2 which obviates the difficulty is: Treat each organic ion separately; before applying Rule 1, add one hydrogen for each negative charge, and subtract one hydrogen for each positive charge.

Although not stated explicitly by Gillis, it is obvious that his method must not be applied to molecular compounds, complexes, hydrates, etc., without either treating each portion separately or using $(n - m + p)$ for the number of rings and multiple bonds, where p is the number of molecular entities in the complex.

W. H. T. Davison

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To the Editor:

When I demonstrate to my first-term chemistry classes the experiment entitled "The Preparation and Properties of Chlorine," I tell them that the chemist always prefers to collect gases by water displacement. I then state that the reasons for this preference are twofold: first, since the water acts as a seal there is less likelihood for the escape of gas into the room (with possible unpleasant effects upon the mucous membranes and lungs); second, the gas when collected by water displacement is likely to be of higher purity. (In water displacement, when the water is out the gas is in, whereas by air displacement the gas is more likely to be contaminated with air.)

From the above statements I develop that it follows, therefore, that when chlorine is not collected by water displacement the gas must be assumed to be fairly soluble in water and therefore has to be collected by air displacement. However, this method of collection by air displacement has always been distasteful to me and I decided to try some liquid other than water.

Since some of this research was performed a couple of years ago I cannot remember with certainty all the liquids with which I experimented, but the list included kerosene, mineral oil, carbon tetrachloride, chloroform, and mercury. The last-named, to my chagrin, gave me calomel. None gave me the proper results.

Recently I gave renewed thought to this problem and wrote to Dow Chemical Company for guidance. I asked them if they could suggest a liquid in which chlorine was but slightly soluble and which did not react with chlorine. They suggested the use of saturated solutions of calcium chloride or sodium chloride. I might have thought of these myself except, possibly, I felt others must have experimented with them and proved them to be of little value.

Upon trial, however, I found the calcium chloride solution eminently effective, and the sodium chloride solution only scarcely less so. Chlorine could remain trapped overnight by this method, with little dissolved in the liquid by morning.

Then I thought I would compare water with these solutions. The result astonished me. I was able to collect the chlorine with no trouble at all and, in addition, I collected one bottle of chlorine and allowed it to remain in full view upon the stand in a glass pneumatic trough and directed the pupils' attention, occasionally, to the gradual rise of water in the bottle. I checked with the publishers of many of the high-school laboratory manuals and learned that all used the conventional air displacement method.

Of course, the gas first prepared was not collected. It was run into a solution of hypo as usual and allowed to escape in order to eliminate displaced air from the generating bottle. Carbon dioxide, by the way, is collected by water displacement and chlorine is only slightly more than twice as soluble. I intend to use the water displacement method hereafter unless it can be proved that it has undesirable features.

Milton G. Wolf

James Madison High School
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To the Editor:

Rasárnava is one of the famous chemical treatises of ancient India. This writing has been placed not later than the thirteenth century A.D. Some historians prefer to put Rasárnava in the twelfth century A.D. In this work the following flame tests for metals are mentioned:

> Copper gives a blue flame
> And tin a pigeon color,
> Lead is pale tinted
> And iron is dull yellowish brown.

Flame tests described for other metals and ores are ambiguous because of defective rendering of the manuscript. It seems that the author of the Rasârnava first noticed the difference in the color of metallic flames. It will be interesting to know if there is any mention of flame tests in the literature earlier than Rasârnava.

Tapan K. Mukherjee

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ATOMS AND ENERGY

H. S. W. Massey, F. R. S., Quain Professor of Physics, University of London. British Book Centre, Inc., New York, 1953. 174 pp. 14.5 × 22 cm. $3.50.

PROFESSOR MASSEY'S objective is to help the non-technical reader appreciate what is taking place during the release of nuclear energy. He is concerned with both the particles and the energy involved, and he starts from scratch with both subjects.

In the first chapter, he takes up the three fundamental particles and how they fit into our picture of atomic structure. Then he shows how atoms combine into molecules and describes the magnitude of the chemical forces involved. The quantities of energy liberated in nuclear transformations are enormously greater than are possible in any chemical reaction. The reason for this is explained and a number of techniques for studying nuclear changes are described.

In the fourth chapter he discusses fission and fusion reactions and methods for concentrating U^{235}. In Chapter 5 he turns to atomic energy at the service of man, and the final chapter carries the reader into frontier research on cosmic rays, mesons, and the new ether.

Professor Massey's handling of energy concepts is particularly effective. Although he has no particular flair for dramatic presentation, well-chosen diagrams and photographs supplement a carefully written text. He has an American audience in mind when he consciously avoids using "billion" in the English sense, but he does use "nucleic" instead of "nuclear," and there are a few other unfamiliar terms.

The science student as well as the intelligent layman will find this book helpful and interesting.

RICHARD WISTAR

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ORGANIC CHEMISTRY: AN ADVANCED TREATISE

Edited by *Henry Gilman,* Iowa State College, Ames, Iowa. John Wiley & Sons, Inc., New York, 1953. Vol. III: xxxviii + 580 pp. 39 figs. 48 tables. Vol. IV: xxxviii + 665 (581–1245) pp. 20 figs. 30 tables. 15.5 × 23.5 cm. $8.75 per volume.

THE success and usefulness of the original two volumes of Gilman's advanced treatise have now been augmented by the appearance of the third and fourth volumes covering twelve further topics in organic chemistry. In each instance it has been necessary for the specialist to write a composite and selective review of the recent developments in the field and this is supplemented by the inclusion of many recent literature references and general references to more extensive treatises.

Volume III. "The study of organic reaction mechanisms," by Paul D. Bartlett of Harvard University, comprises an excellent introduction to an increasingly important aspect of organic chemistry. The chapter begins with an outline of principles and methods applied in the study of organic reaction mechanisms. This is followed by a discussion of the displacement reaction, reactions of alcohols, ethers, halides, and the carbonyl group.

Foil A. Miller of the Mellon Institute has written the chapter on "Applications of infrared and ultraviolet spectra to organic chemistry." Applications of data from the two spectral regions to analysis, structure determination, characterization, and other problems of the organic chemist are described and evaluated. Of special value are a chart and table of characteristic infrared group frequencies and a table of characteristic ultraviolet absorption bands.

The chapter on "Lipids" is divided into two parts; the first section on simple lipids, written by J. C. Cowan of the Northern Regional Research Laboratory, covers the origin and uses of fats, the identity and distribution of acids in fats, the reactions of the free acids and synthetic glycerides; the second section on the compound lipids, written by H. E. Carter of the University of Illinois, covers the sources and chemistry of such phospholipids as lecithin, cephalin, and phosphatidyl serine and such sphingolipids as sphingomyelin, cerebrosides, and gagliosides.

The chapter on "Organic dyes" is written by H. W. Grimmel of the Metro Dyestuffs Corporation of West Warick, Rhode Island, and is a fairly extensive survey of organic colorants but emphasizes those known to have been used commercially. Methods of synthesis starting with common intermediates, properties of dyes, effect of structure and substituents on shade and fastness are given for the standard groups of dyes. Both old and more recent literature and patent references are listed.

The discussion of "Some aspects of chemotherapy," by Dr. H. R. Ing of the University of Oxford, is kept within the bounds of the definition given by Paul Ehrlich; that is, the treatment of infections by chemical substances which are toxic to the microorganism but relatively harmless to the host. Dr. Ing uses the topics antiseptics and disinfectants, antimalarials, trypanocidal agents, and arsenical drugs, to present the relationship of functional groups, molecular structure, and physical properties of the chemotherapeutic agents to the effect on the microorganisms. Although very few methods of synthesis of the drugs are given, literature references to this information are in abundance.

The topic of "Antibiotics" is treated by Dr. Lee C. Cheney of Bristol Laboratories as a discussion of the representative degradation reactions, approaches to or total syntheses of the three important commercial antibiotics—penicillins, streptomycin, and chloromycetin. The physical properties, physiological activity, and source of many other antibiotics are tabulated at the end of the chapter.

Volume IV. "The terpenes," by Richard H. Eastman and Carl R. Noller of Stanford University, begins with a discussion of monoterpenes and proceeds through the intermediate classes to the polyterpenes. The fascinating chemical behavior of these compounds is represented by various synthetic and degradative reactions of acyclic and cyclic members of each class.

The chapter "Heterocyclic chemistry," by Richard H. Wiley of the University of Louisville, is an excellent 178-page introduction to, or review of, this important field of organic chemistry. The five- and six-membered ring heterocyclic compounds of oxygen, sulfur, and nitrogen are included. The discussion of each ring system includes the feasible methods of preparation, the important substitution and addition reactions and conditions under which the rings are opened.

The short chapter on "Starch," by W. Z. Hassid of the University of California, reviews the more recent work of American, English, and Continental investigators on starch to 1953. The subjects include the characterization and proposed chemical constitution of amylose and amylopectin, approaches to molecular-weight estimation, the crystalline structure and helical configuration of starch, the noncarbohydrate substances in starch, starch esters and ethers, and enzyme action on starch.

The chapter on "Chemistry of explosives," by George F Wright of the University of Toronto, is restricted to developments in explosives since 1943 or to information released from security regulations since that time. An introduction discusses experimental and calculated heats of explosion, the qualitative estimation of explosive types from the types of bonds and different atoms involved, the sensitiveness of explosives and explosion initiation. The explosives chosen for discussion include aliphatic nitrate esters; the nitro compounds, TNT, picric acid, tetryl, and hexonite; the nitramine, cyclonite; guanidine nitrate, and nitroguanidine and derivatives.

As one would surmise from the title of the chapter "Reactions of organic gases under pressure," by W. E. Hanford of M. W. Kellogg Company and D. E. Sargent of General Aniline and Film Corporation, the emphasis is on industrial reactions and thus the majority of the references are from the patent literature. About one-half of the chapter is devoted to a discussion of the polymerization of alkenes. The remainder of this section concerns other reactions of alkenes, oxidation and substitution of alkanes, polymerization of and addition to acetylene, and a brief mention of the reactions of carbon monoxide and dioxide.

In the chapter on "Oxidation processes," William A. Waters of Balliol College, Oxford, considers all of the oxidizing agents of importance to organic chemists. The discussion centers largely on mechanisms of action of the reagents in the course of which the range of applicability of each is delineated.

HAROLD A. IDDLES
HENRY G. KUIVILA
ROBERT E. LYLE

UNIVERSITY OF NEW HAMPSHIRE
DURHAM, NEW HAMPSHIRE

● ATOMS, MEN AND GOD

Paul E. Sabine. **The Philosophical Library, New York, 1953. x + 226 pp. 14 × 22.5 cm. $3.75.**

THE author of this book has a problem which he thinks may be a common one among scientists who have not put science in the place of religion in their lives. He states his problem thus: "Can I be intellectually honest in believing what as a Christian I profess to believe and at the same time accept the teachings of modern science and psychology regarding the nature of man and God in the physical world?"

He tries to show evidence of a spiritual evolution paralleling the very probable physical evolution. He says science and religion have "common ground" in man, and "common origin" in the first reactions of primitive man toward his environment. A pattern of development of scientific thought is then traced through seven chapters showing how the findings of modern science, which does not propose to explain first causes, serve to highlight the existence of an Intelligence directing nature. Science is seen from a religious point of view.

In the final chapter the author endeavors to look at Christian faith from a scientific point of view by regarding it as a "mutation" in the spiritual evolution of man. The historic facts of Christianity, he says, are explained as an "extension of the idea of purposive evolution." In the soul of Jesus "there arose to human consciousness an Idea, a spiritual reality. The expression in one perfect human life of the Idea of God in Man is both natural and supernatural in the same way as are the origins of Life and Mind."

As an alternative to a scientific approach to the problem "of the antithesis of the natural and the spiritual in the origin of Christianity" he chooses to examine the Gospels, which accounts he regards as "unfortunately...tradition and legend." The fourth Gospel he regards as interpretative of events in the life of Jesus in terms of the prologue, "In the beginning was the Word (*Logos*) and the Word was with God and the Word was God....." By an act of rational religious faith, he says, one may identify the creative will of the evolutionary process with the *Logos* of John's Gospel, but notes that in the evolutionary Will there are no ethical or spiritual implications. This act of faith, he says, can regard Jesus either as a perfect man or as the "uniquely divine Son of God." Therefore, he concludes, His teachings may be accepted as any well grounded theory would be. In the future evolution of society, he thinks, the great issue is whether the unfolding is to be guided by Marxian materialism and Communism or by the ideals of Jesus.

This reviewer found some parts not too clear. The following quotations would lead one to wonder what is the author's concept of God, if not the final, ultimate reality.

Page 12:"...we must think of Nature and God, not as two separate existences, but as two aspects of a single final reality that includes both the natural and the divine."

Page 216: "If that faith (in a loving Father and a world order ruled by love) should die out in human hearts then the story of the man of Galilee...would have to be relegated to the limbo of myth and outgrown superstition."

Page 219:"...that realization (of the free, conscious Self) comes only with the mystical yet wholly rational experience that God and the atoms and the human soul are one in essence, a spiritual trinity, three expressions of the unity of the living soul of a living universe."

On page 212 there is a misprint of "World" for "Word" in the quotation from the Fourth Gospel.

On the whole, the author seems to recognize that science has tried to know only the world and remains ignorant of the most important truths about it. The world is intelligible only in terms of both man and God. This understanding he would have strictly rational and scientific. He has accomplished his purpose in that he offers for consideration, to scientifically-minded scholars reared in the Protestant tradition who have a "will to believe," such a solution of a common problem. He feels that he has offered at least a detour around some bothersome difficulties, *e. g.*, he gives substantial reasons for having confidence in the teaching of Christ even if one does not believe He is God.

For those who know science, but have no faith, the book might be an incentive to search further. This in itself would make it well worth the writing. For those who have the gift of faith and who follow the direct road of revelation with no conflicts, Chapters 3 through 7 are a fairly comprehensive survey of the development of scientific thought and theory. Furthermore, they may find it pleasant to have faith confirmed by science and to find illustrated the fact that truth is one.

SISTER M. CONSILIA HANNAN

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● GENERAL BIOCHEMISTRY

Joseph S. Fruton **and** ***Sofia Simmonds,*** **Professor of Biochemistry and Assistant Professor of Biochemistry and Microbiology, respectively, Yale University. John Wiley & Sons, Inc., New York, 1953. xii + 940 pp. Illustrated. 15.5 × 23.5 cm. $10.**

THIS is a welcome arrival in the field of biochemistry. Written for the graduate student, it treats the subject of biochemistry at an advanced level, yet assumes no previous training in the field. A thorough grounding in chemistry at the undergraduate level should, however, precede a course in which this text is used. Although written primarily for the graduate student in biology or chemistry it should also serve as an excellent text for a medical-school biochemistry course.

The authors have adopted a fresh approach to the presentation of biochemistry. The first part of the book is devoted to an extensive discussion of the structure and chemistry of the proteins, a subject on which the authors can write with considerable authority. This is followed by sections on enzyme chemistry and biological oxidation. Then come sections on the chemistry and metabolism of the carbohydrates and the lipids. The metabolism of proteins and nucleic acids follows, and the book concludes with a section on the role of inorganic ions, hormones, and vitamins in

metabolism. Quite properly for a text of this kind, the clinical implications of biochemistry are kept to a minimum.

Recent developments in the field of biochemistry are discussed and recent references are cited. For example, the literature on α-lipoic acid is reviewed to September, 1952. The recent developments are placed in a proper perspective by a judicious use of historical material. For example, the authors lead up to a discussion of the chemical nature of enzymes with a historical introduction in which work of van Helmont, Réaumur, Liebig, Berzelius, and others is discussed and which includes a statement by M. Traube indicating that he viewed enzymes as proteins as early as 1858.

The reviewer questions whether some of the material which is included might not have been omitted. Considering that this text was written for the mature student, the material on equilibrium and thermodynamics in Chapter 9 could have been shortened and covered by a reference to a standard text on the subject. Also it was surprising to find on page 22 an elementary discussion of the meaning of pH—surely not needed in a book for the graduate student.

An important feature of this text is the inclusion of many references. Some of these are to original papers—particularly those which have appeared within recent years. In addition there are many references to review articles.

The text is written in a lucid and pleasing style and appears to be remarkably free from errors. This book should prove to be an excellent text for graduate students in biochemistry and a ready reference work for all who are working actively in the field of biochemistry.

ARTHUR H. LIVERMORE

REED COLLEGE
PORTLAND, OREGON

ESTIMATION OF ORGANIC COMPOUNDS

F. Wild, **Fellow of Downing College, University of Cambridge. Cambridge University Press, New York, 1953. vii + 239 pp. 29 figs. 14.5 × 22.5 cm. $5.**

DR. WILD has now produced a book dealing with methods for the quantitative determination of functional groups in organic molecules as a companion volume to his "Characterization of Organic Compounds," which was published in 1947 and dealt with the qualitative aspects of organic analysis. The present volume appeared in May of this year and in great detail discusses quantitative methods (both macro and micro) of estimation of the groups: olefinic double bond, alcoholic, enolic, and phenolic hydroxyl (with additional specific procedures for methanol), thiol, the carbonyl group in aldehydes and ketones (including special methods for formaldehyde, acetaldehyde, benzaldehyde, acetone, and methyl ethyl ketone), amino, nitro, cyano, nitroso, isocyano, isothiocyano, acetyl, benzoyl, methoxyl, ethoxyl, propoxyl, butoxyl, methyl and ethylimino, methyl and ethyl groups attached to sulfur, and methyl groups attached to carbon.

As with the previous volume, this work is of greatest value for the research worker and is of more limited use to a beginning student. Although many procedures are described in detail, the thoroughness of Dr. Wild's approach to those groups which he has chosen to include has necessitated his presenting the less widely applicable methods in abstract form. However, the entire book is copiously documented, so that any lack of detail works no hardship on those using it. The chemical, biological, medical, pharmacological, agricultural, and food technological literature has been consulted through 1951.

The author indicates in his preface to the book that one of his aims is to bring to the general attention many of the new improved laboratory techniques which are rarely mentioned in textbooks of organic chemistry, and which "remain unnoticed and untried, although often they would give better results." He fulfills this aim, and presents a much more comprehensive survey of available techniques than is presented in the usual laboratory book. To illustrate, he describes in detail eleven techniques for the estimation of olefinic unsaturation and in abstract form outlines nine more. Although the detailed techniques are not new in concept, recent modifications of the older methods are included. For example, among the procedures given for determining the bromine number of an olefin are included three modified procedures from the recent literature. As a further example, the new sensitive Schwarzenbach and Wittwer (1947) modification of the Kurt Meyer method is referred to among older methods for determining enol content. When they are available, completely new procedures are added to the older ones. For the determination of active hydrogen the Zerewitinoff method on both a macro and a micro scale is described, but, in addition, detailed directions are given for the recently developed determination using lithium aluminum hydride [J. A. KRYNITSKY, J. E. JOHNSON, AND H. W. CARHART (1948)].

In addition to the table of contents, subject index, and author index, each section of the present volume is preceded by an outline of the methods to be discussed, which adds to the convenience of the user. The volume is remarkably free of typographical errors. In view of the fact that the book is essentially aimed at the research worker, the author's inclusion of a common method for determining liquid densities or, for example, descriptions of the use of the Abbé and the Pulfrich refractometer has puzzled this reviewer. Anyone unfamiliar with the use of a refractometer is not likely to be sufficiently enlightened by the present descriptions.

The above is minor criticism indeed of a careful, thorough, up-to-date treatment of those aspects of organic analysis which fall within the scope of the author's intentions. The book will make a useful addition as reference work to the libraries of all those who, in widely diversified fields, are doing research with organic compounds.

FRANCES BERLINER

BRYN MAWR COLLEGE
BRYN MAWR, PENNSYLVANIA

DATA FOR X-RAY ANALYSIS

Volume I: *W. Parrish* and *B. W. Irwin,* Philips Laboratories, Inc., Irvington-on-Hudson, New York. 100 pp. Volume II: *W. Parrish, M. G. Eckstein,* and *B. W. Irwin,* Philips Laboratories, Inc. 82 pp. Philips Technical Library, North American Philips Co., Inc. 21.5 × 30 cm. Paper bound. $2 per volume.

THE charts in Volume I give graphical solutions to the Bragg equation, $\lambda = 2d \sin\theta$. The spacing d is plotted as a function of θ and 2θ in the range of θ from 0° to 90° for the $K\alpha$, $K\alpha_1$ and $K\alpha_2$ wave lengths of molybdenum, copper, cobalt, iron, and chromium. Routine calculations in powder diffraction analysis may thus be simplified since the spacing d may be obtained directly from the charts, once the value of θ has been found from measurements on the film.

These charts are intended primarily for identification of powder samples from X-ray diffraction data, since it is not possible to use them with sufficient accuracy for the precise determination of lattice constants.

Volume II contains tables for use in precise calculation of the lattice constant of cubic crystals. The tables consist of values of $\sqrt{h^2 + k^2 + l^2} \cdot \lambda/2$ for each reflection hkl for the $K\alpha$, $K\alpha_1$, and $K\alpha_2$ wave lengths of copper, nickel, cobalt, iron, and chromium. From the experimentally obtained values of θ for each reflection, $\sin\theta$ is found from some good book of tables and then the cubic cell length is found from

$$a = \sqrt{h^2 + k^2 + l^2} \cdot \frac{\lambda}{2} \cdot \frac{1}{\sin\theta}$$

The values of a thus obtained may be plotted against some function of θ, two of which are tabulated in this volume, and then extrapolated to $\theta = 90°$ to give a precise value of the cell constant.

The tables are attractively laid out and are easy to read.

For the specialists concerned with cubic crystals they represent a considerable saving in time and labor.

DAVID R. DAVIES

California Institute of Technology
Pasadena, California

● LABORATORY STUDIES IN COLLEGE CHEMISTRY

Joseph A. Babor, Professor of Chemistry, College of the City of New York, and _Alexander Lehrman,_ Associate Professor of Chemistry, College of the City of New York. Thomas Y. Crowell Co., New York, 1952. xii + 277 pp. Line diagrams and tables. 27.5 × 20.5 cm. $2.50.

This laboratory manual consists of a compilation of 72 exercises in which the students are directed to check, in the laboratory, the qualitative properties of those substances commonly introduced into the course for college chemistry.

There seems little doubt that, as the authors say in their preface, "All of the experiments have been carried out by students, and none is beyond the capabilities of the average college freshman." Unfortunately, there is little to excite the interest of a better-than-average student. A first-class student would probably spend a good deal of his laboratory time repeating activities performed quite adequately in high school.

The directions are clear, though labored in places, and the illustrations, though well done, are tiny.

An unusual feature of this book consists of complete page references, for each of the experiments, to 21 textbooks of college chemistry.

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Chico State College
Chico, California

● THE PROTEINS: CHEMISTRY, BIOLOGICAL ACTIVITY AND METHODS. VOLUME I, PART A

Edited by _Hans Neurath,_ Department of Biochemistry, University of Washington, and _Kenneth Bailey,_ Department of Biochemistry, University of Cambridge. Academic Press, Inc., New York, 1953. xi + 548 pp. 108 figs. 16 × 23.5 cm. $12.

During the last few years a number of books have appeared in which various phases of protein chemistry have been the subject of review. This is as it should be, for the progress toward an understanding of the complete structure of proteins has been very rapid during the last decade. The application of new physical and chemical techniques and the results from such diverse approaches to the problems of protein structure necessitate frequent and critical discussion.

The present book is the first part of a two-volume treatise (each volume to consist of two parts) in which the editors hope "to present a comprehensive, integrated account of the chemical, physical, and biological properties of the proteins." Part A consists of six chapters in which general properties of proteins are discussed.

In Chapter 1, J. F. Taylor surveys the various methods, chemical and physical, that have been employed for the isolation of proteins. The precautions necessary to avoid denaturation, the evaluation of homogeneity, and the preservation and stabilization of proteins are considered in detail. Under the heading "The general chemistry of amino acids and peptides," P. Desnuelle (Chapter 2) presents qualitative and quantitative reactions of amino acids and methods of separation of peptides. The results of studies on peptide structure before and after partial hydrolysis and peptide synthesis are included. The author has given few details of these many methods but has over 500 literature citations.

G. R. Tristram, in Chapter 3, critically evaluates the methods that have been employed in the determination of the amino acid composition of proteins and the results of protein analysis. He emphasizes the precautions that have to be taken in order to achieve high accuracy, essential when the results are to be applied to a consideration of protein structure.

In a very detailed chapter (Chapter 4), B. W. Low approaches the problems of structure and configuration of amino acids, peptides, and proteins from the results of crystal structure, X-ray diffraction, and X-ray crystallographic studies. The problems of molecular configuration of folded or coiled polypeptide chains in fibrous and globular proteins, the nature of interchain bonding and the resulting intermolecular packing are critically considered. The limitations as well as future possibilities of X-ray methods in evaluating protein model structure are discussed. Also, in considerable detail, P. Doty and E. P. Geiduschek report in Chapter 5 on optical properties of proteins such as birefringence, refraction, optical rotation, ultraviolet, infrared and polarized infrared spectra, and photochemical reactions.

In Chapter 6, R. A. Alberty writes on the electrochemical properties of proteins: their ionization and acid-base binding capacity and titration. The methods and theory of moving-boundary electrophoresis are considered in detail as well as the electrophoresis-convection method. The application of these methods to the analysis of protein mixtures, their use as a criterion of purity and as a means of preparing pure proteins are discussed.

Extensive literature references, some as late as 1952, are given as footnotes by all the authors. The indexes will appear in the second part of Volume I.

F. A. CAJORI

University of Colorado School of Medicine
Denver, Colorado

● THE HARVEY LECTURES

Delivered under the auspices of The Harvey Society of New York, 1951–52. Series 47. Academic Press, Inc., New York, 1953. viii + 271 pp. Illustrated. 14 × 21 cm. $7.50.

The following titles and authors are included: "The nucleotides: Some recent chemical research and its biological implications," by A. R. Todd; "Hydrostatic pressure affecting the flow of urine and blood in the kidney," by F. R. Winton; "An ascending recticular activating system in the brain stem," by H. W. Magoun; "Studies on the cellular immunology of acute bacterial infections," by W. Barry Wood, Jr.; "Metabolic blocks in carbohydrate metabolism in diabetes," by I. L. Chaikoff; "Morphogenesis and the metamorphosis of insects," by Carroll M. Williams; "The development of the cerebral cortex: A cytological, functional, and biochemical approach," by Louis B. Flexner; "Coagulation of the blood," by Walter H. Seegers; "Some biochemical studies based on chromatographic methods," by L. Zechmeister.

● SELECTED VALUES OF PHYSICAL AND THERMODYNAMIC PROPERTIES OF HYDROCARBONS AND RELATED COMPOUNDS: COMPRISING THE TABLES OF THE AMERICAN PETROLEUM INSTITUTE RESEARCH PROJECT 44 EXTANT AS OF DECEMBER 31, 1952

Frederick D. Rossini, Professor of Chemistry, Carnegie Institute of Technology, _Kenneth S. Pitzer,_ Professor and Dean of the College of Chemistry, University of California, _Raymond L. Arnett_ and _Rita M. Braun,_ Carnegie Institute of Technology, and _George C. Pimentel,_ Assistant Professor of Chemistry, University of California. Carnegie Press, Pittsburgh, Pennsylvania, 1953. ix + 1050 pp. 21 × 27.5 cm. $7.

A critical review of a book like this is impossible, but even a casual inspection will lead one to agree with the Advisory Committee of the A. P. I. that "this volume serves as today's standard of physical and thermodynamic data on hydrocarbons."

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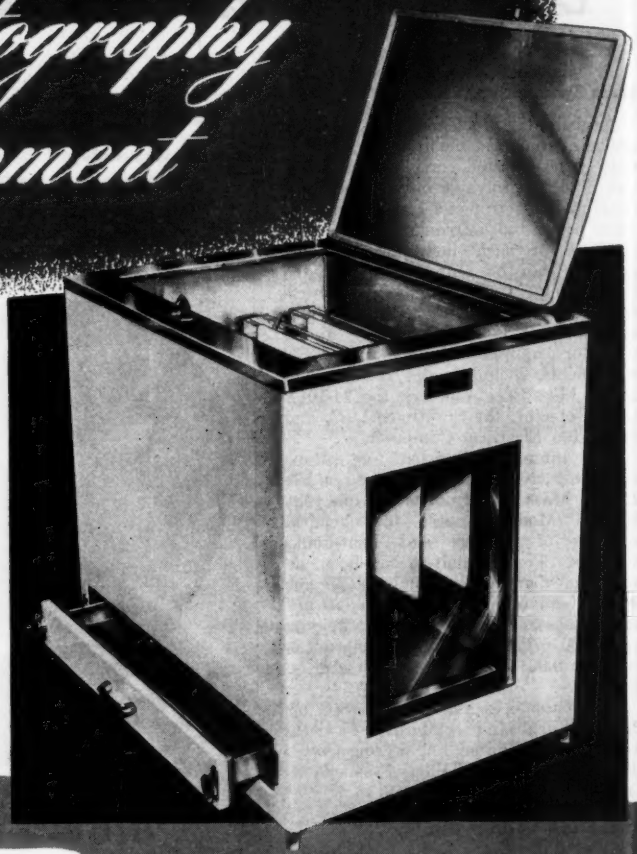

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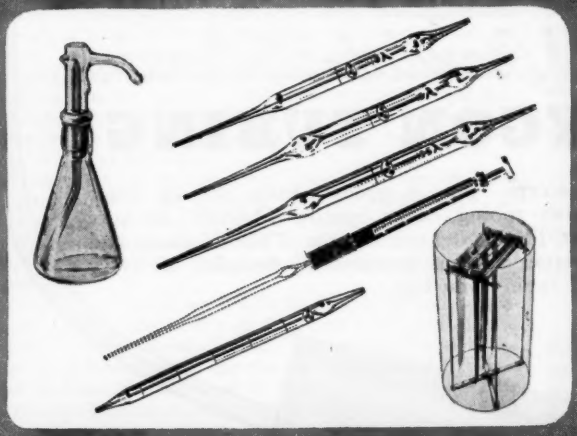

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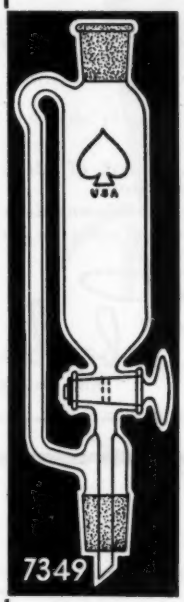

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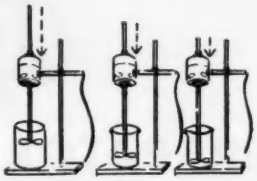

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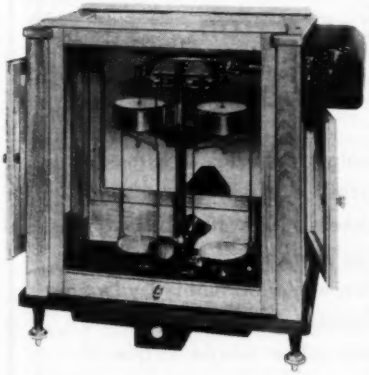
Built by Stanton Instruments, Ltd., London, the precision balances are used principally in laboratory weighings, where both speed and accuracy are needed. Features of the line, which meets a wide variety of scientific applications, are damping cylinders which arrest beam rapidly, and planes of synthetic sapphire (corundum), which provide the uniformly hard surface required for maintained sensitivity.



The Burrell Corp., manufacturers and distributors of laboratory apparatus, is located at 2223 Fifth Ave., Pittsburgh, Pennsylvania. The addition of the Stanton balances distributorship will greatly extend the service the firm renders users in the scientific field of this type of equipment.

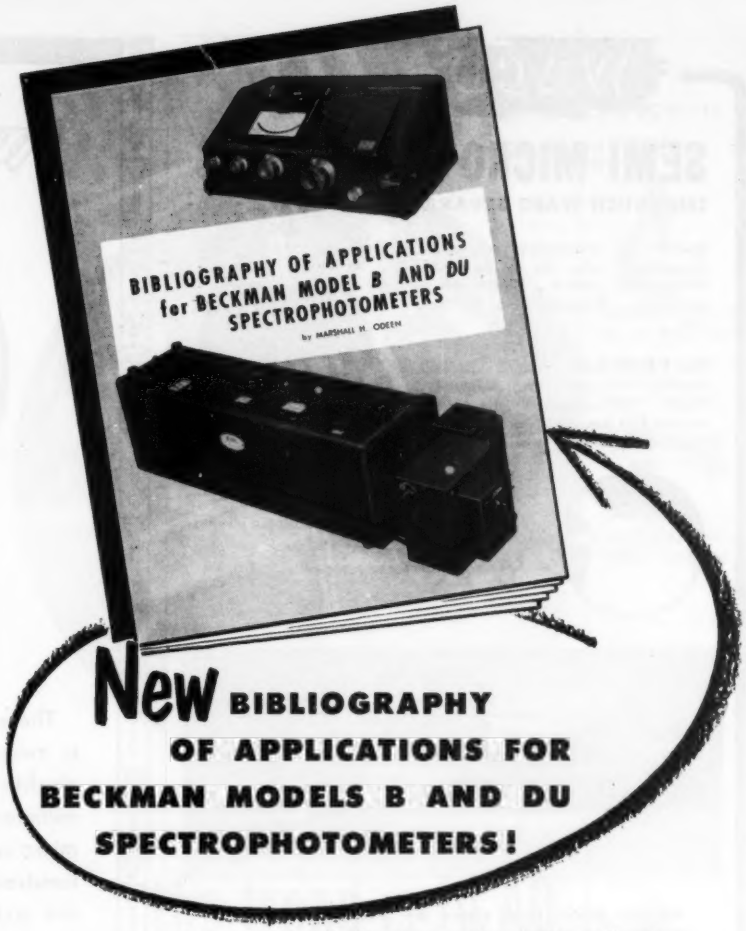
New Literature

● The current issue of "Labitems" published by the Emil Greiner Company is devoted exclusively to petroleum testing apparatus. Most of the instruments shown in the bulletin were designed and built in Greiner's own shops.

Copies of "Labitems" are available on request from the Emil Greiner Company, 20 N. Moore St., New York 13, New York.

● Brochures on "Facts about Silicon Carbide" and "Facts about Aluminum Oxide" are available from The Carborundum Co., Niagara Falls, New York.

● A new unit-type electrophoresis-diffusion instrument, featuring double sensitivity in an optical system based upon double passage through the cell, is described in a new folder available from Specialized Instruments Corp., 670 O'Neill Ave., Belmont, California. Suggested for application in the analysis, study, and identification of electrically active particles in biological and chemical research fields, the new unit is illustrated in detail. Descriptions are given of the five individual optical facilities included; of the auto-



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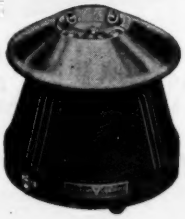

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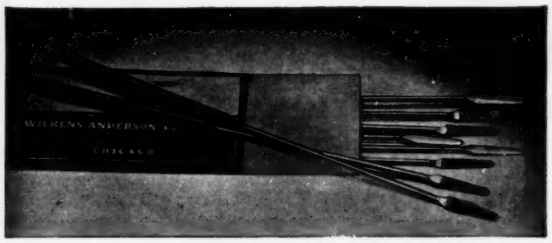

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● Metalab Equipment Corp. has published a brochure describing its sectional units for assembling complete laboratories and offering free aid in planning the setting up of new laboratories making use of these units. Among the items of equipment featured are fume hoods, center and wall tables, and combinations thereof, storage cabinets, service fixtures, and all types of accessories which complete the laboratory. For your copy of this 12-page, 2-color brochure, write to Metalab Equipment Corp., 214 Duffy Ave., Hicksville, Long Island, New York.

● Harshaw Scientific, Division of The Harshaw Chemical Co., 1945 East 97th St., Cleveland 6, Ohio, offers a 12-page booklet entitled, "Supplying the Nation's Laboratories." Featured are items available for various types of laboratories, including those geared for Control, Research, or Development work. Among these items are the Norelco X-Ray Spectrometer and Spectrograph Leco Carbon & Sulfur Apparatus, Buehler Polisher, International Centrifuge, and many other instruments, and lines of equipment. For your copy of "Supplying the Nation's Laboratories" write directly to Harshaw Scientific.

● Standard Scientific Supply Corp. announces a new issue of their "Laboratory Apparatus" bulletin, a 12-page 2-color catalog, describing various items, including the Coleman "8" colorimeter, the Standard heat gun, laboratory carts, "AO" sterile fluids pump, desiccating cabinets, electrothermal heating tapes, etc. For your free copy, write to Standard Scientific Supply Corp., 34 West Fourth St., New York 12, New York.

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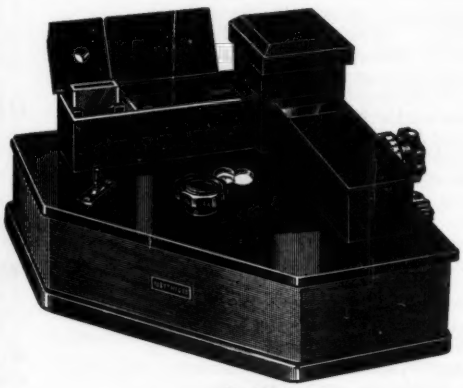

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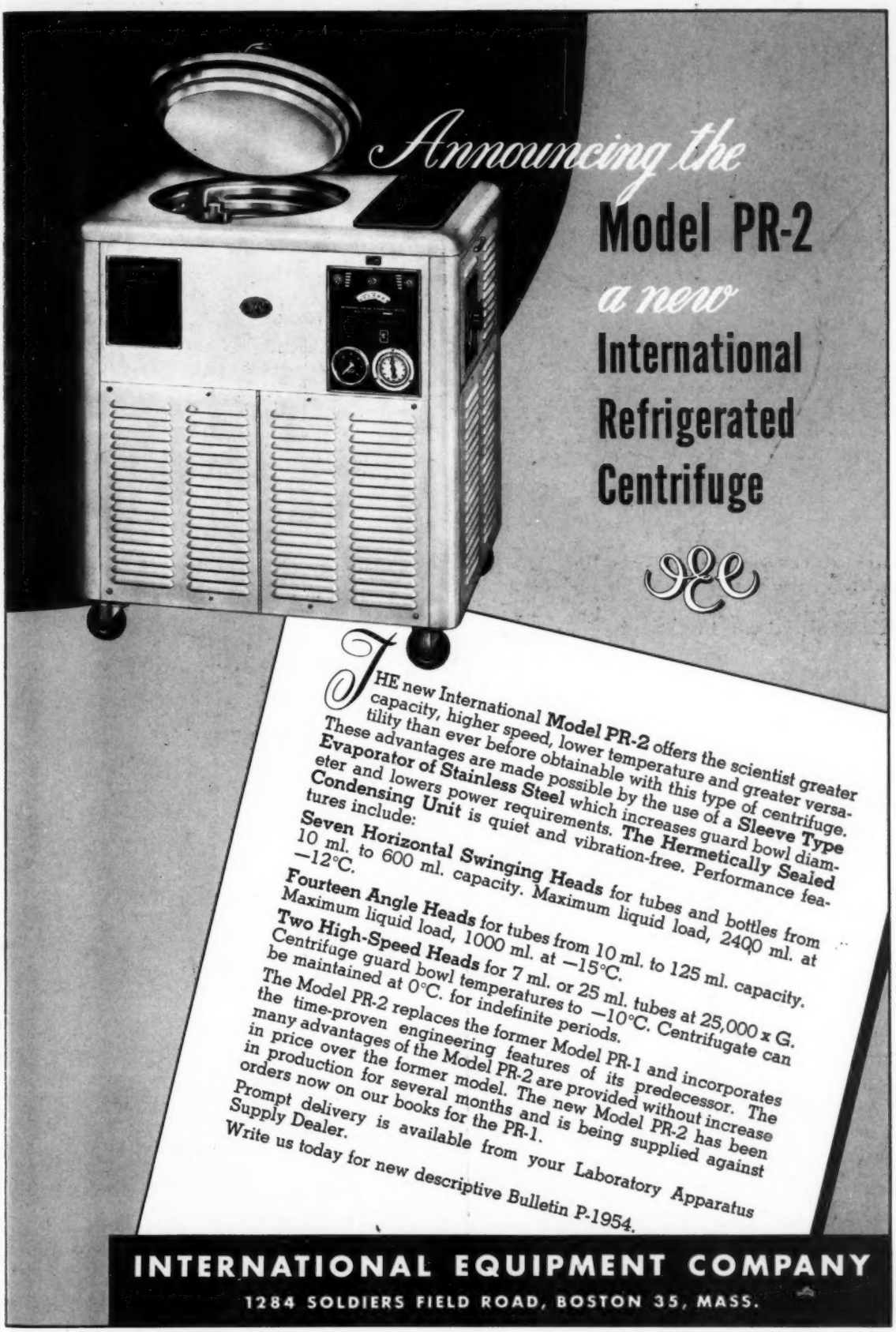

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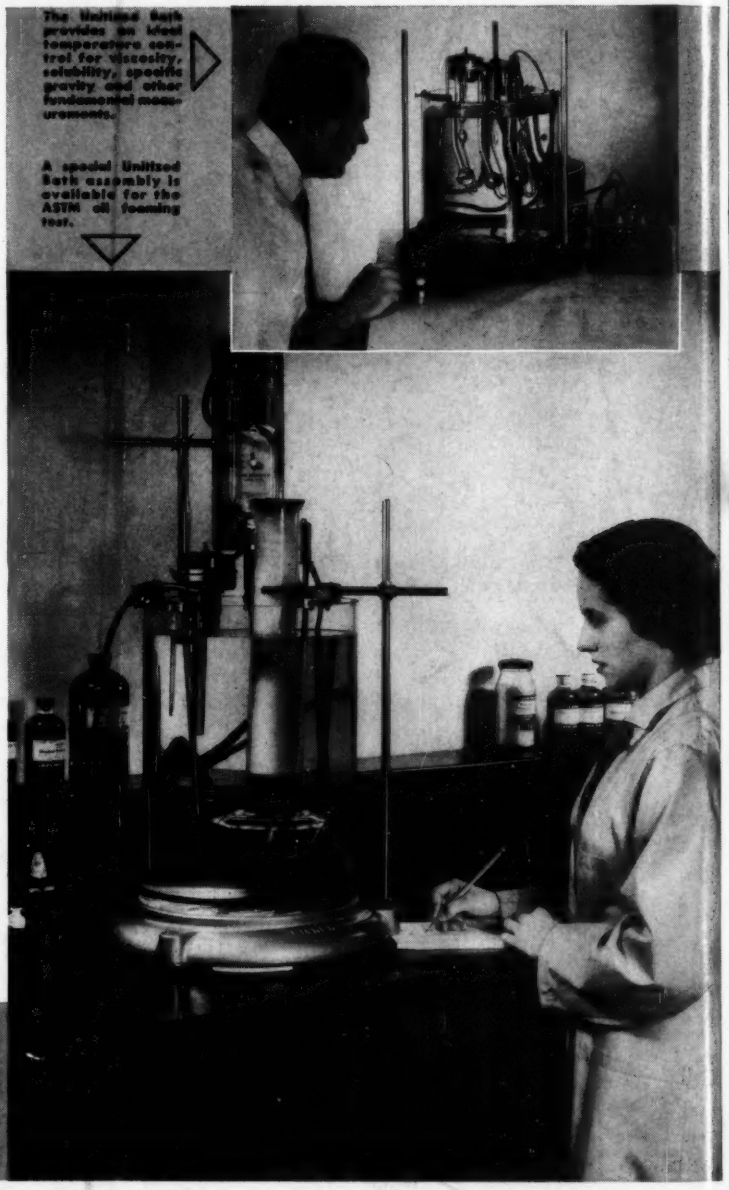
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